Design environment of solutions

Deliverable D10.3

Version N°1.0

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Abbreviations and acronyms

Acronym	Description
BACS	Building Automation Control System
BEMS	Building Energy Management System
BIM	Building Information Modelling
BIPV	Building Integrated Photovoltaics
BIST	Building Integrated Solar Thermal
BRP	Building Renovation Passport
CCAM	Cooperative, Connected and Automated Mobility
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilisation
CCUS	Carbon Capture, Utilisation and Storage
CDR	Carbon Dioxide Removal
CHP	Combined Heat and Power
CHCP	Combined Heat, Cooling and Power
CIM	Civil Information Model
D	Deliverable
DH	District Heating
DHN	District Heating Network
DH&C	District Heating and Cooling
DNSH	Do No Significant Harm
EC	European Commission
EE	Energy Efficiency
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
ETC	Evacuated Tube Collectors
EU	European Union
EV	Electrical Vehicle
FPC	Flat Plate Collector
GHG	Greenhouse Gas
GI	Green Infrastructure
HP	Heat Pump
ICT	Information and Communication Technology
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IoT	Internet of Things
ITS	Intelligent Transport System
JRC	Joint Research Centre
LCC	Life Cycle Cost

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Acronym	Description
MSW	Municipal Solid Waste
NBS	Nature-based Solutions
NZEB	Nearly Zero-Energy Buildings/ Blocks
PV	Photovoltaic
PVT	Photovoltaic Thermal
RES	Renewable Energy Sources
SECAP	Sustainable Energy and Climate Action Plan
SME	Small and Medium Enterprise
SRI	Smart Readiness Indicator
SUD	Sustainable Urban Drainage
SUDS	Sustainable Urban Drainage System
SUMP	Sustainable Urban Mobility Plan
WP	Work Package
WWTP	Wastewater Treatment Plant

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Summary

This deliverable defines and details a **wide set of solutions to address the reduction in emissions across all sectors** (or emission domains) in cities. It is the second and final outcome of Task 10.2 "*Analysis of solutions, co-benefits and barriers to adoption",* within WP10 "*State-of-the-art expert services on thematic areas*". This deliverable is meant to support climate neutral cities development through a **solutions catalogue**, which contains more than **170 solutions and 12 concepts,** that is accessible in the Knowledge Repository within the Portal, including the design environment conditions for the solutions with information based on examples, case studies and cities' implementation experiences.

Such solutions are organised around **eight Thematic Areas:** Stationary Energy; Energy Generation; Mobility and Transport; Green Industry; Circular Economy; Nature-based Solutions; Digital Solutions; and Enabling Instruments.

Furthermore, each solution is described in in a **Factsheet**, which contains detailed information that has been developed in two steps. First step was reported in D10.2 "*Catalogue of solutions and co-benefits"*, and included the detailed description of the solution, the tags (relation to thematic areas, categories and other tags defined in the NZC Portal), some visuals (photograph, graphics, schemes…), as well as the related co-benefits (previously defined and categorised in: climate resilience, health, social, economy, resource efficiency and biodiversity), and external links, which included both links to reference information and to examples and case studies.

The second stage of this Solutions Catalogue is reported through the present deliverable (D10.3 "*Design environment of solutions"*), which builds upon the previous fields of D10.2 and adds the **design environment conditions** for the solutions. The latter one outlines the pre-conditions and enabling conditions, constraints/barriers for implementation, instruments or processes for implementation, drawbacks/adverse impacts of the solutions after implementation, and impacts. The impacts are measured using both impact indicators and do no significant harm principle is also considered. Additionally, case studies can be added to provide further information.

The present document includes some **concepts definition**, through the same Factsheet template. A concept is understood in this case as a principle or an idea, which supports climate neutrality city targets, that can combine several solutions together.

Keywords

Thematic Areas; Co-benefits; Technical Innovation; Design Environment conditions; Solution Factsheet; Stationary Energy, Energy Generation; Mobility and Transport; Green Industry; Circular Economy; Nature-based Solutions; Digital Solutions; Enabling Instruments.

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Structure of the document

The document is structured into the following main sections:

- **Section 1** introduces the whole document and why it is necessary for the cities. It includes also the rationale for which the different fields for solutions' analysis have been included.
- **Section 2** includes the **approach and methodology** of the task and deliverable. It starts by putting in **context** the WP10 and the Task 10.2 (**section 2.1**), then the process for the **Solution Factsheet** development, both orange and pink parts, including the templates to develop them (in **section 2.2**) and also the **method fill in the Factsheets (pink fields for the design environment conditions)** with the detailed instructions provided to complete them (**section 2.3**).
- **Section 3** includes the complete catalogue of the **state-of-the-art solutions to address GHG emissions**. It is organised with a section per thematic area, and a subsection per solution, including both the orange part and the pink part; since the orange part has been further complete in most of the cases while developing the other fields. Also, it is highlighted the author of each solution, and the ones that have been covered by JRC, is just pointed out, since it can be seen in the Knowledge Repository. Each solution includes as well the link to access it in the NetZeroCities Portal (links to each solution):
    - **Section 3.1** for Stationary Energy (Buildings);
    - **Section 3.2** for Energy Generation;
    - **Section 3.3** for Mobility and Transport;
    - **Section 3.4** for Green Industry;
    - **Section 3.5** for Circular Economy;
    - **Section 3.6** for Nature-based Solutions and Carbon Sinks;
    - **Section 3.7** for Digital Solutions;
    - **Section 3.8** for Enabling Instruments.
- **Section 4** contains the **concepts** that have been prioritised and then elaborated in the factsheet format, as well as the complete factsheets of the ones developed by WP10 partners.
- **Section 5** describes the **next steps**.
- A section of **Conclusions** is added at the end of the report, as well as a **References** section, which consolidates the references added as footnotes across the report.

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1 Introduction

Global climate change and increasing natural disaster are giving people an awakening call for becoming sustainable and greener[1]. **Climate change** generates impacts and risks that can surpass limits to adaptation and result in losses and damages (IPCC, 2022[2]). The IPCC's 2022 Special Report on Global Warming of 1.5°C warns that current nationally determined contributions for the Paris Agreement are not sufficient. Cities have a key role to play in addressing climate change, given that their emissions remain significant in the EU. **Mitigation actions** are needed to restore and conserve ecosystems and increase their resilience. However, these technical actions cannot come alone and must be integrated into a **systemic portfolio of solutions** that span different policy levers, social innovation, citizens and stakeholder engagement, and other levers that are needed to overcome barriers, and avoid drawbacks. In fact, according to the IPCC 2022 report, taking action requires a combination of governance, finance, knowledge and capacity building, technology and catalysing conditions (IPCC,2022). The integration of these factors can help to ensure that technical solutions are implemented effectively and are supported by a broader context of systemic change. Despite the efforts of some cities to reduce CO_2 emissions, many small and medium-sized municipalities in Europe have not yet taken climate initiatives[3]. Therefore, it is crucial to adopt action as soon as possible and conduct regional and local research on energy and climate governance to develop effective climate action strategies that can be tailored to the specific contexts of these communities.

The present document shows an **analysis of 100 solutions** and what are their associated co-benefits, impacts (qualitative and/or quantitative), typical barriers and enablers (pre-conditions, understood as what is the needed systemic environment around the solution, in terms of policy, regulation, citizens and stakeholders' skills and engagement; that is, what is needed for the successful implementation of the solution) that actors have found, things that went wrong in the process of implementation, and examples from cities across Europe. The analysis aims to become a **valuable tool for cities towards decarbonization**, by providing examples of best practices, identifying challenges and opportunities, generating public awareness and support, informing policy decisions, and encouraging an integrated approach, collaborating with stakeholders and combining solutions.

Design environment conditions: what is most important for cities to know?

Despite the **immense potential for decarbonising cities**, there are still **barriers** for the adoption of technologies. By understanding the enabling conditions and barriers that can affect a city, policy-makers and stakeholders can learn from it, identify potential challenges and opportunities and make informed decisions about how to support the implementation of solutions. For example, high upfront costs of carbon capture technologies or lack of people awareness of the use of fossil fuels can be significant barriers to their widespread adoption. Without addressing these barriers, it can be difficult to achieve meaningful progress towards decarbonization.

The experience of EU Covenant cities has demonstrated the **need for strong policy support** that combines various options of "urban climate governance" to transform the urban structure. To achieve success, it is crucial to establish robust cooperation and partnerships with citizens and local businesses, as shown in Figure 1.

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[1] Wen-Long Shang, Zhihan Lv, Low carbon technology for carbon neutrality in sustainable cities: A survey, Sustainable Cities and Society, Volume 92, 2023, 104489, ISSN 2210-6707, https://doi.org/10.1016/j.scs.2023.104489.

[2] IPCC 2022 Special Report on Global Warming: https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_SummaryForPolicymakers.pdf

[3] JRC report, The Future of Cities: https://urban.jrc.ec.europa.eu/thefutureofcities/climate-action#the-chapter

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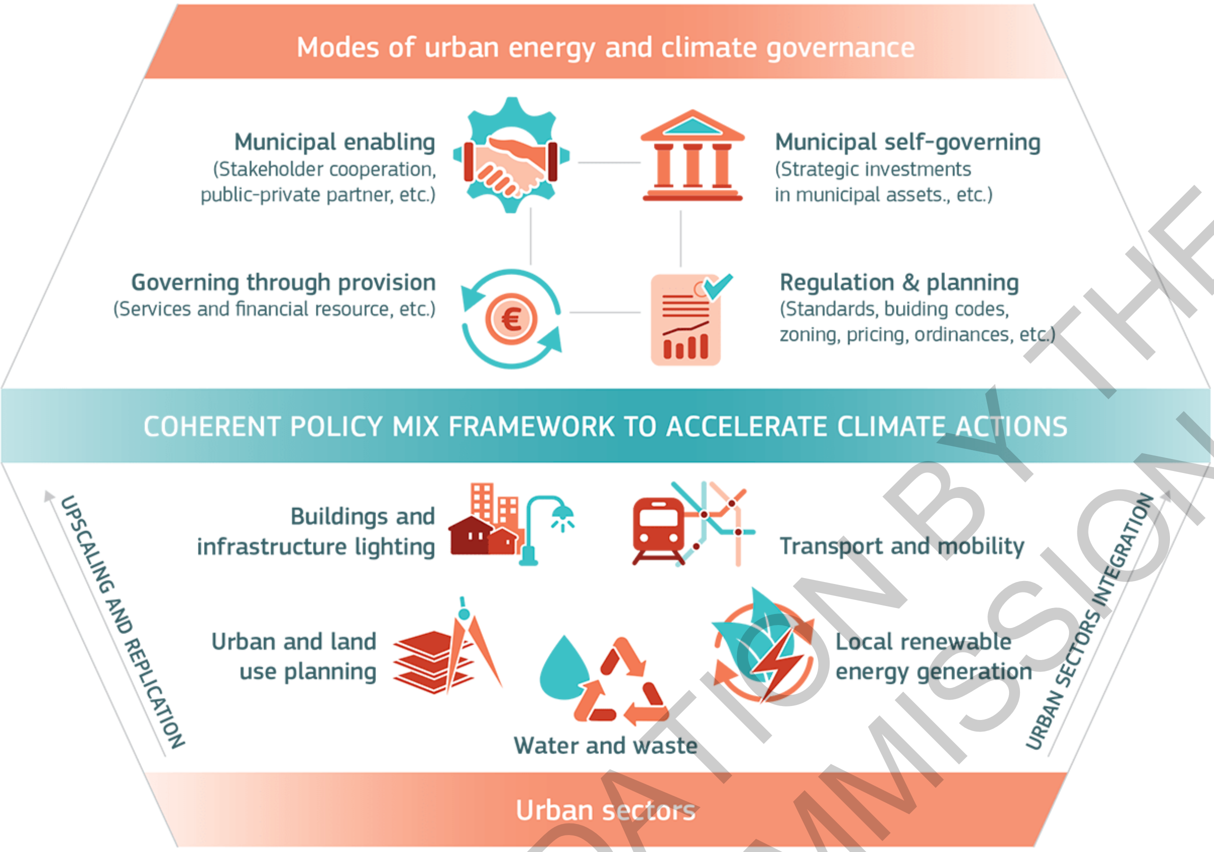

Figure 1: Modes of urban energy and climate governance, including urban sectors. Source: JRC[4]

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Local authorities have the ability to establish regulations and urban planning principles that support energy efficiency, sustainable transport, and local renewable energy production. Through municipal enabling, they can mobilize actors and provide additional policy support. Additionally, local authorities can act as implementers by investing in energy-efficient municipal assets and promoting renewable energy sources. Municipal self-governing and raising awareness among public servants and different departments are critical for implementing climate action plans.

The **enabling factors**, on the other hand, can facilitate the adoption and implementation of solutions, such as policies and regulations that incentivize the use or adoption of a technology, portfolio co-creation with citizens and stakeholders (through workshops, surveys or focus groups), creation of social campaigns to increase public awareness and support for sustainable practices, or the availability of financing options for energy-efficient building upgrades. These **instruments and processes for implementation** are described in the present deliverable, for the technical solutions identified across the seven thematic areas. Identifying and leveraging these enabling factors can help accelerate the adoption of solutions.

Furthermore, the **impacts** such as GHG reduction or reduction of primary energy consumption, as well as the **co-benefits** that will be achieved by implementing the solution are identified. The impacts can help the city to address which solutions can contribute to their portfolio of actions towards climate neutrality, and whether or not the **Do Not Significant Harm (DNSH) principle** is respected. Examples showcasing the adoption of the solution will be presented to learn from best practices, anticipate potential obstacles and opportunities that have been effective in other contexts, and generate public awareness and stakeholder support.

[4] https://urban.jrc.ec.europa.eu/thefutureofcities/static/images/sections/assets/modes-of-gov.png

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In the following Table 1, the fields to identify and describe the enabling factors of the solutions through the Factsheets are depicted.

Table 1: Design Environment conditions fields of the Factsheets

Field in the Factsheet	Description
Pre-conditions and enabling conditions	The necessary characteristics a city might have (climate, geography, urban form, renewable energy potential, infrastructure in place, etc.), and the supporting factors (policy, funding, financing instruments, socio-economic context, and governance and stakeholder engagement) that are in place, and that can allow (prior to implementation) the successful adoption of the technologies.
Constraints and barriers for implementation	It indicates which barriers are most commonly found in cities that can hinder the implementation of a solution. The barrier analysis aims to help a city understand what can happen in their city, and analyse if the city can have those barriers as well, which will need to be overcome through the supporting factors listed above and below.
Instruments and processes for implementation	Indicates which technical, policy, funding, financing, governance and stakeholder engagement instruments can support the implementation of the solution. It links with smart solutions and non-technical methods/instruments/case studies within the Knowledge Repository
Drawbacks and adverse impacts of the solutions after implementation	The possible drawbacks and pros or cons that are materialised as part of the implementation of a solution. It is intended that this field is described with the help of the example of different and diverse case studies.
Impacts	Quantitative and/or qualitative indicators that can be achieved by the implementation of the solution are listed here. Furthermore, the analysis of how the solution affects or Do Not Significant Harm (DNSH) principle is done.

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2 Approach and Methodology

2.1 WP10 and Task 10.2 context

The **WP10 "*State-of-the-art expert services on thematic areas*"** is aimed at sourcing proven solutions that can support cities in the climate neutrality pathway, which means to adopt climate neutrality and social innovation actions, and to design services to facilitate their local demonstration and uptake. The main objectives of WP10 are to:

- **Map and characterise proven solutions** in the defined **thematic areas**, as well as the requirements for the **suitable design environment**, understood as the needed context for successful implementation of solutions.

- Map and analyse how cities can achieve different **co-benefits** when deploying solutions (see Figure 2 for the list of co-benefits from WP10).

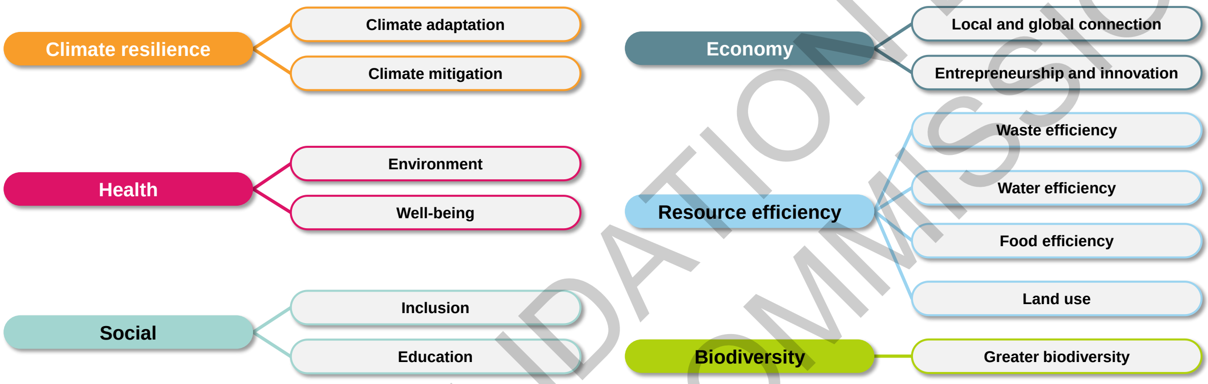

Figure 2: NetZeroCities WP10 co-benefits definition

- Design **3 levels of services** for the cities, to feed into the NetZeroCities Portal and Platform (see Figure 3 for the structure of the three service levels in WP10).

SERVICE LEVEL 1	Accessible through the **Knowledge Repository** Public: all users & Cities	**Information**: **Solutions Catalogue** (Task 10.2), **Knowledge-Smart repository** (organised in a dynamic way and gathering cities' feedback)	Connected to: **external websites**
SERVICE LEVEL 2 Demand-driven	Accessible through the **P2P Collaboration Tool** Mission cities	**Tailored advisory service**, for detailed support (through **City Advisors** and meetings/ calls/ **workshops**, webinars and other **Capacity Building** activities)	Connected to: **City Advisors** & **Capacity Building** activities
SERVICE LEVEL 3 Demand-driven	Accessible through the **P2P Collaboration Tool** ***(& Interactive Tools module)*** NZC Pilot Cities	**Expertise to design** and demonstrate solutions (in the Pilot Cities), possibly combining solutions from catalogue. Experts: project partners or from Community of Practice	Connected to: **City Advisors & WP3 & WP4** for services delivering to Pilot Cities

Figure 3: NZC Three service levels in WP10

The **Task 10.2 "*Analysis of solutions, co-benefits and barriers to adoption*"** is aimed at describing best practices (solutions and concepts) among the defined thematic areas (see Figure 4). The main outcome of this task is the federated **catalogue** of state-of-the-art and proven solutions, which is in the form of Factsheets, included in **section 3** of the present report, as well as in the form of navigable website of the Knowledge Repository in the NetZeroCities Portal.

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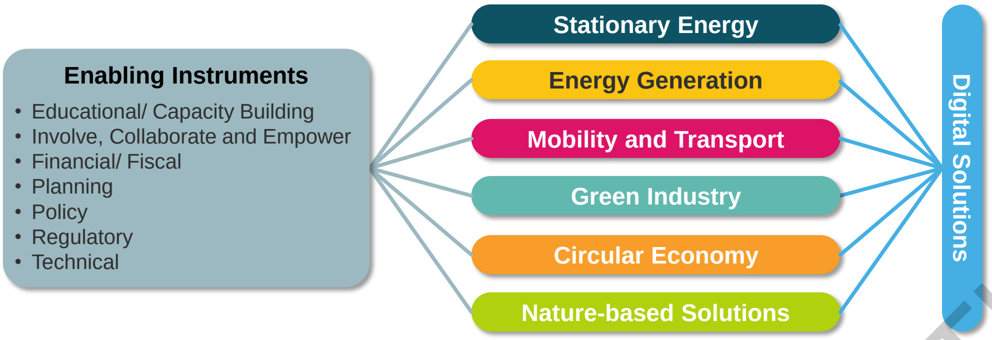

Figure 4: NetZeroCities Thematic Areas

This catalogue (with up of 180 solutions) supports innovative and interoperable technical and non-technical local climate actions in the sectors of stationary energy (buildings), energy generation, mobility and transport, and green industry, as well as exploiting the benefits of the enablers of circular economy, nature-based solutions, digital solutions, and instruments. Figure 5 below shows the scheme with the idea of the WP10 Solutions Catalogue and how it is built and feed with information.

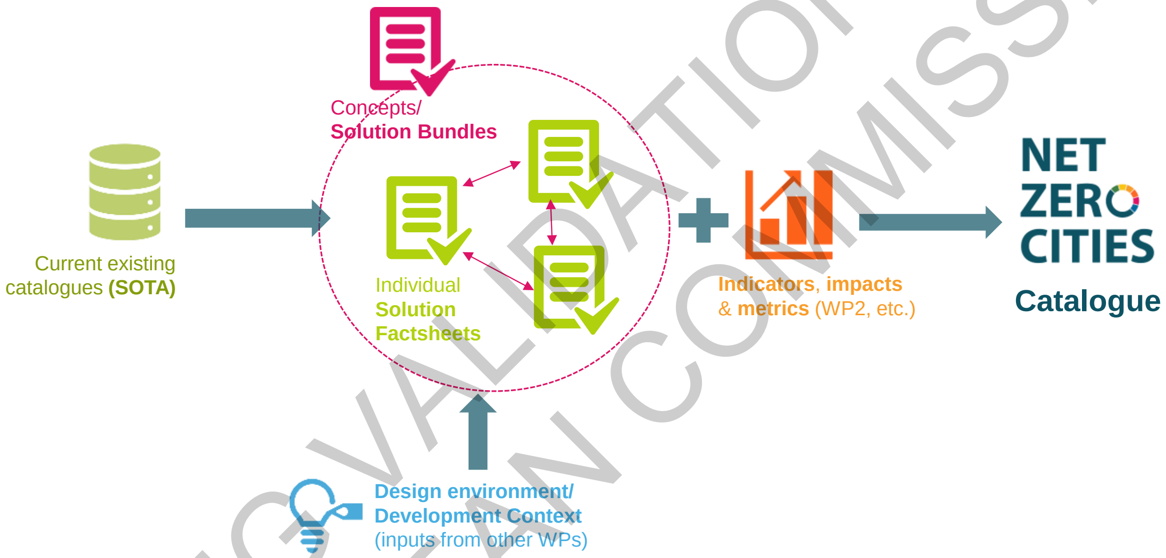

Figure 5: WP10 Catalogue of Solutions for the NZC Knowledge Repository structure

Each solution is described in in a **Factsheet**, which contains detailed information that has been developed in two steps. First step was reported in D10.2 "*Catalogue of solutions and co-benefits"*, and included the detailed description of the solution, the tags (relation to thematic areas, categories and other tags defined in the NZC Portal), some visuals (photograph, graphics, schemes…), as well as the related co-benefits (previously defined and categorised in: climate resilience, health, social, economy, resource efficiency and biodiversity), external links, which included both links to reference information and to examples and case studies. The second step of this Solutions Catalogue is reported through the present deliverable (D10.3 "*Design environment of solutions"*), and adds to this previous "orange" fields, the "pink" ones, consisting in the design environment conditions for the solutions, i.e. pre-conditions and enabling conditions, constraints/barriers for implementation, instruments or processes for implementation, drawbacks/adverse impacts of the solutions after implementation, impacts (including both impact indicators and do no significant harm principle considerations), and additional information from case studies.

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2.2 Solution Factsheet

To develop the Solutions Catalogue, a template with guide and instructions was set. Each solution (except for the ones of Enabling Instruments, which are enablers themselves) has two parts, orange fields with the more general solution information, and pink fields, with the information about the design environment conditions.

The "orange" fields in the template (see Figure 6) include the **description** of the solution; **visuals,** as attractive visual aid, such as images, diagrams, photographs, schemes, etc.; **tags,** including those of the thematic area and categories, as well as the additional ones defined in the Portal; the related **co-benefits**, from the defined list in WP10, explaining why each relates with the solution; relation and connection with other solutions in the Knowledge Repository (**keywords**); **external links** to include websites for reference information; and **examples**, to add examples or case studies from implementation in cities.

SOLUTION FACTSHEET NET ZERO CITIES

SOLUTION	**Name in short version**
TAGS	**Thematic areas and other tags**
DESCRIPTION	**Description of the solution**, why is it useful, what can be achieved by deploying the solution, how it can be connected with other solutions/areas, etc. - *Minimum of 100 words* - ***Maximum of 200** /300 words*
VISUAL	ADD **attractive visual aid** (images, videos, diagrams…) - *At least one visual reference!*
CO-BENEFITS	Text explaining the relation of co-benefits that the solution has (**co-benefits** from the list highlighted in **bold text**)
KEYWORDS	ADD other solutions with **direct connection** with the present one or that can have an **indirect connection** (i.e. to form a package or bundle of solution, to form a concept or an integrated solution).
EXTERNAL LINKS	ADD **external links to websites**, other catalogues (if in PDF, indicate page), or Case Studies (**examples** of implementation in cities), with relevant related information - *When possible, add **at least two external sources** of information/references*
EXAMPLES	ADD **links to Case Studies** (**examples** of implementation in cities), with relevant related information - *When possible, add **more than one example***

Figure 6: Template for the Solution Factsheets (orange fields) with instructions to fill it in

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The "pink" fields in the template (see Figure 7) include **pre-conditions and enabling conditions** (prior to the implementation of the solution), **constraints and barriers** for the implementation of the solution, **instruments** or processes that enable the implementation, **drawbacks and adverse impacts** after the implementation of the solution, **impacts** (including indicators to provide quantification and DNSH principle considerations), as well as a field to add further information from case studies.

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PRE-CONDITIONS & ENABLING CONDITIONS	**Potential enablers, conditions for success** or **what is needed in the city environment ideally** (prior to the implementation) to ensure a successful implementation of the solution. Use the following pre-defined categories where relevant: - *Climate and geography* - *Urban form and layout* - *Technical aspects/ infrastructure* - *Policy and regulatory/legal framework* - *Funding and Financing* - *Economic and social context* - *Project governance and implementation modalities*
CONSTRAINTS/ BARRIERS FOR IMPLEMENTATION	**Main barriers/obstacles** that should be considered and what are the most typical barriers found that **can hinder the implementation** of the solution. Use the following pre-defined categories where relevant: - Climate and geography - Urban form and layout - Technical aspects/ infrastructure - Policy and regulatory/legal framework - Funding and Financing - Economic and social context - Project governance and implementation modalities
INSTRUMENTS/ Processes for implementation	From the list of ***Enabling Instruments*** and ***other NZC's resources***, that can help as **enablers** to deploy or promote the implementation of such solutions (and **explain** why, in what way)
DRAWBACKS/ ADVERSE IMPACTS OF THE SOLUTIONS after implementation	**What went wrong** in some Case Studies/examples, what can be wrong with the implementation of the solution. Describe possible **drawbacks and pros/cons** from implementation extracted from **at least 3 relevant Case Studies**.
IMPACTS (Indicators + DNSH)	**Impact indicators** and try to **provide quantification** (from examples/ Case Studies): - ***Emissions*** *indicators* - ***Energy consumption*** *indicators* - ***Cost*** *indicators (investment cost, operational costs)*
	General considerations to be taken into account for the **Do No Significant Harm (DNSH)** principle. Risks infriging the DNSH principle (to the environmental objectives of the EU) when deploying in a city environment.
ADDITIONAL INFORMATION FROM CASE STUDIES	Bullet points from **Case Studies**: **highlights,** focus on information about **timeline** for implementation, **costs…**

Figure 7: Template for the Solution Factsheets (pink fields) with instructions to fill it in

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The Solution Factsheets are then uploaded as "resources" in the Knowledge Repository (https://netzerocities.app/knowledge). To upload them it is necessary to have an account in the Portal, the process is quite straightforward, although it has to be done one by one:

- In the Knowledge Repository, go to "**My resources**"

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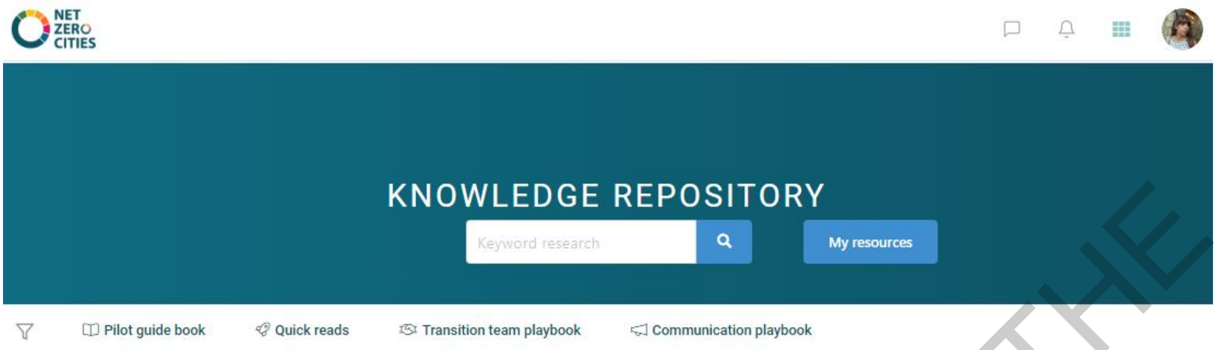

Figure 8: Main page of the Knowledge Repository (for a NZC Portal user)

- Then click on "**Add resource**"

Figure 9: Screen within "my resources" in the Knowledge Repository

- In the "Add a new resource" panel, we select "**Article**"

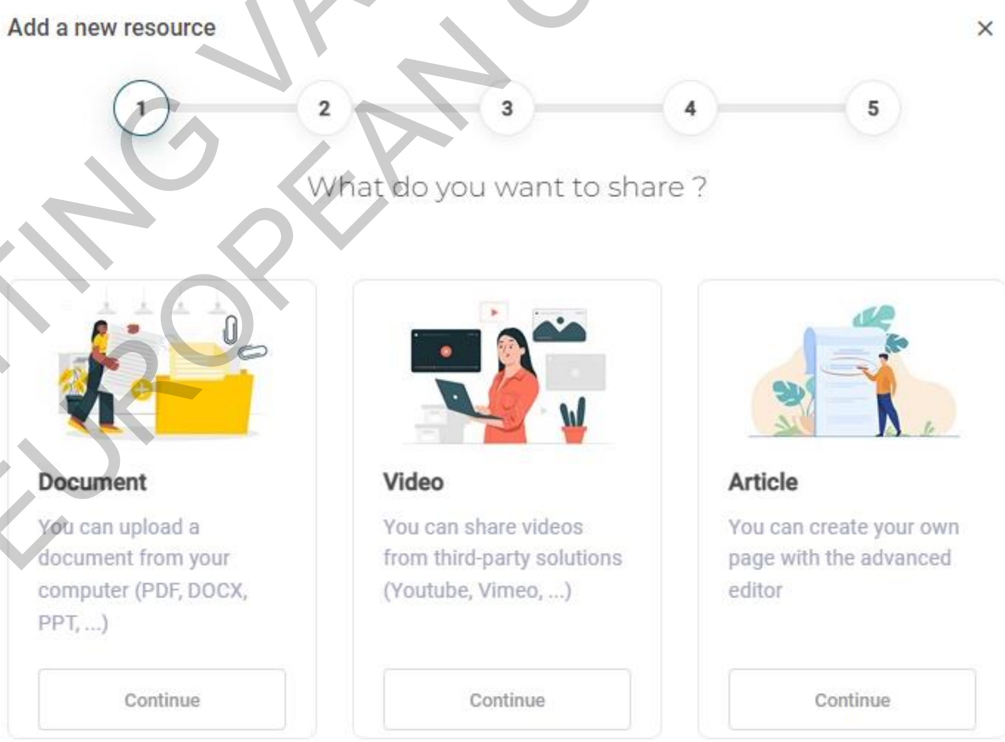

Figure 10: Selection of the type of resource to be added in the Knowledge Repository

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- In the second step, we add the name of the factsheet (in the field for **title**), then the **description**, and we select also the Resource Type: "**Factsheet**".

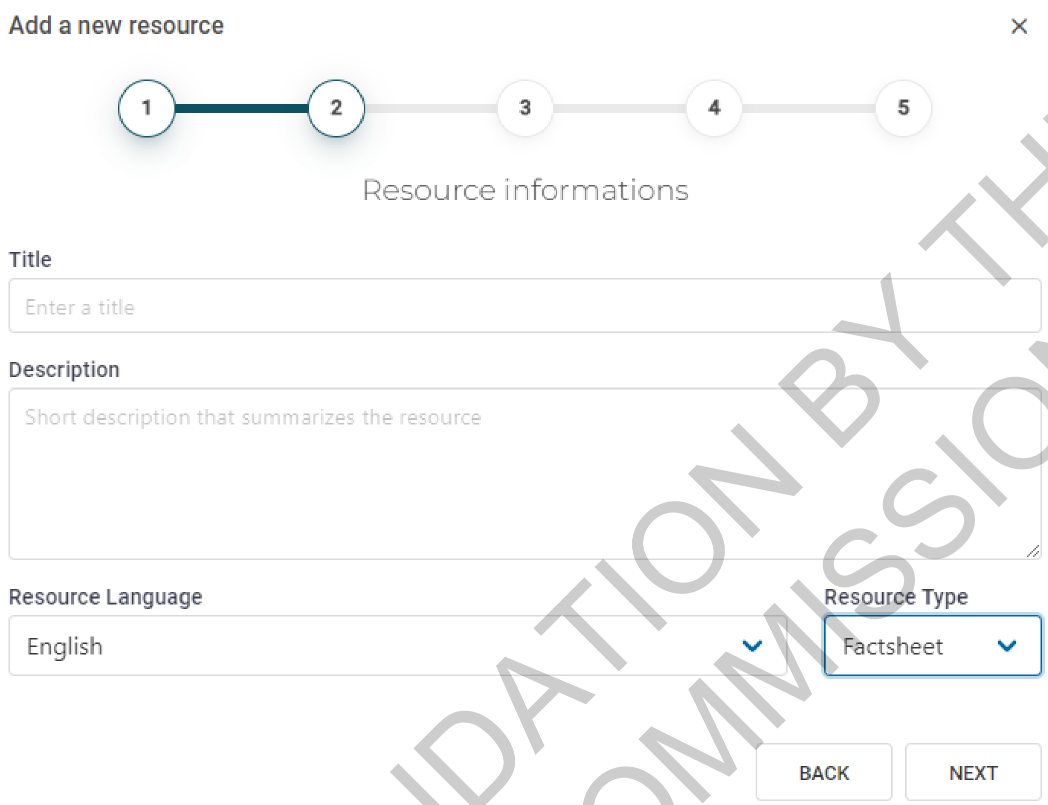

Figure 11: Completion of initial information of the resource to be added in the Knowledge Repository

- Then, we need to **select the tags**, from the ones proposed in fourth screen for adding a new resource. They are organised in three main groups: "Social & Economy", "Sustainable environment" and "Science and Technology". For the nature of the WP10 and the whole bunch of resources developed in there, almost all factsheets include the tags "technology" (because of the nature of technical solutions) and "climate resilience", as they are all solutions for climate neutral cities. Then, depending of the thematic area and the solution itself, other tags are selected accordingly.

- Finally, **license** is assigned to the resource. As all information added in the Knowledge Repository, licenses are CC BY-NC-SA.

- From that, a **new screen** is opened, in which we need to **complete each of the fields of the Factsheet**, including editing the description if we want to edit text (such as adding bold text, italics, separate paragraphs, add the visuals, etc.). The **authors and content curators** are also added in this last phase.

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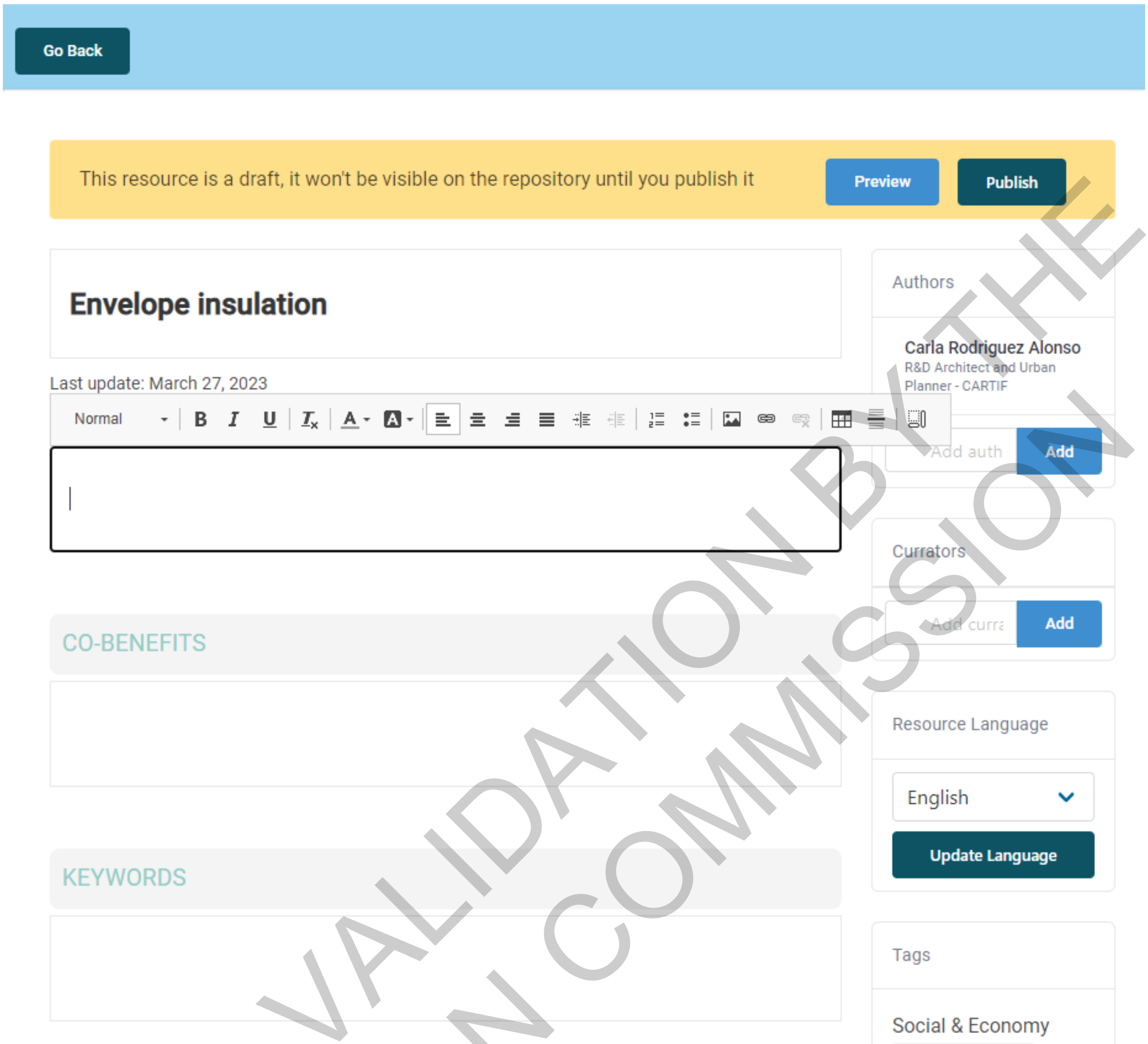

Figure 12: Final step to add a resource in the Knowledge Repository where all the information within each of the fields (orange and pink fields according to the template) is completed

All the content has been uploaded in this way to the Knowledge Repository by Cartif, but this means that Cartif (single individuals from Cartif, as the NZC Portal only allows individual user profiles) will appear as **Curator** of all resources. This has been done in this way for two main reasons, one is to align and harmonise in the best way the format and content in there, and the second one is related to the resources in WP10, for which most of the partners have quite limited effort and almost expend in the elaboration of the solution factsheets in the template.

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2.3 Method to fill in the Factsheets

The general approach taken to develop the Factsheets has been to consult scientific literature, grey literature (project reports, reports), specifically the repository of EU-funded R&I projects, and other research projects, case studies, and application.

The information is aimed to be concise, with bullet points, and trying to connect existing solutions in the NetZeroCities Knowledge Repository, across levers, and to connect with other catalogues of solutions or platforms in the EU.

And, one of the higher recommendations is to **add explanations and examples** where needed. Going forward, the Factsheets will undergo continuous updates that will incorporate examples from NetZeroCities pilots as well as examples that cities are eager to share.

As practical considerations overall, the non-applicable categories for certain solution can be skipped.

Pre-conditions and enabling conditions – guide

This field is intended to indicate both pre-conditions/minimum requirements and enabling conditions/ideal design environment, using the relevant pre-defined categories (keep this order within each of the pre-defined categories).

As practical considerations, it is not a requirement to distinguish between pre-conditions/enabling conditions where this is not easily possible. And, where a distinction between pre-conditions and enabling conditions is being made, it is not a requirement to divide the categories among the two (i.e. categories can be appearing both under pre-conditions and enabling conditions).

Pre-defined categories (indicative):

- ***Climate and geography***: climatic conditions; geographic location (e.g. mountainous, coastal); natural assets (e.g. river, forest); heritage assets (e.g. conservation).
- ***Urban form and layout***: e.g. city size; land use.
- ***Technical aspects/infrastructure***: existing city infrastructure (structures and services) and local R&I infrastructure, including enabling digital and data infrastructures (e.g. ICT, IoT, big data analytics, environmental monitoring; electricity grid infrastructure); standards and interoperability; transport infrastructure, highly-energy intensive industry within city boundaries, usable surface areas.
- ***Policy and regulatory/legal framework***: relevant EU/national laws, standards and regulations; distribution of state powers/competences (e.g. decentralisation); strategic alignment with regional/national objectives; data policy (incl. use, access and sharing).
- ***Funding and financing***: fiscal decentralisation and own resources; incentives; subsidies; availability of private capital; access to EU funding; innovation procurement. You can refer to the following resources already available in the Knowledge Repository:
    - Wards Corner, Public-Commons Partnership (PCP): https://netzerocities.app/resource-2631
    - Civic Design Lab Oakland: https://netzerocities.app/resource-2387/
    - Lada and Velilla Carrion River Social Innovation Platform: https://netzerocities.app/resource-2775/
    - Road/ Congestion pricing in transport: https://netzerocities.app/resource-1668/
    - Blended finance for Energy Efficiency (EE): https://netzerocities.app/resource-1658/
    - Loans for Energy Efficiency (EE): https://netzerocities.app/resource-1648/
    - Antwerp's Participatory Budget: https://netzerocities.app/resource-2923/
    - Participatory Budget: https://netzerocities.app/resource-358/

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- Agirre Lehendakaria Center's Community Listening and Activation Process: https://netzerocities.app/resource-348/
- Just Transition Fund: https://netzerocities.app/resource-80/
- LIFE: https://netzerocities.app/resource-77/
- European City Facility (EUCF): https://netzerocities.app/resource-75/
- Greenprint for Investment – Glasgow: https://netzerocities.app/resource-45/
- Climate Finance Lab: https://netzerocities.app/resource-41/
- Financing the Green Transition: https://netzerocities.app/resource-39/
- Green Bonds Programme-Kenya: https://netzerocities.app/resource-35/
- EIB's Attempt to Drive Capital to Revenue-Generating Resilience Projects: https://netzerocities.app/resource-33/
- Optimization of the mix of private and public funding to realise climate adaptation measures in Malmö: https://netzerocities.app/resource-31/
- Green Urban Financing and Innovation Project: https://netzerocities.app/resource-30/
- Hamburg's Green Roof Strategy: https://netzerocities.app/resource-27/
- Oslo Sustainable Procurement strategy: https://netzerocities.app/resource-25/

- ***Economic and social context***: demographics (e.g. composition, household type); GDP per capita vs cost of take-up; digital divide vs inclusion; citizen awareness, education and digital skills.

- ***Project governance and implementation modalities***: models of public services design and delivery, including: engagement and participation of citizens and local private/public stakeholders (e.g. city (sectoral) departments, research institutes, industry/businesses) and mobilisation of collective knowledge and skills (in the local administration; R&I skills); citizen-engagement and co-creation initiatives, stakeholder consultation, public-private partnerships; experimentation/testing needs, contracting of services including maintenance, and implementation by citizens/private companies.

Constraints / Barriers for implementation – guide

This field is to indicate main barriers that can hinder the implementation of the solution, using the relevant pre-defined categories (from previous section).

Instruments / Processes for implementation – guide

It may be used the list of Enabling Instruments provided (**section** ¡Error! No se encuentra el origen de la referencia.) as a starting point.

The Enabling Instruments listed in this document may have been already mentioned/introduced in the section on pre-conditions/enabling conditions. The recommended approach is to keep this section rather concise and provide the substance/description in the section on pre-conditions/enabling conditions (i.e. do not repeat information in this section; limit this section to tagging the instrument and providing if needed a short 1-2 sentences explanation).

Drawbacks / Adverse impacts of the solutions after implementation – guide

This field is to describe possible drawbacks, and pros/cons that materialised as part of implementation.

The indicative approach here, besides the consultation of scientific literature and so on, is to illustrate it with at least three of the most relevant case studies (where possible). In the selection of such case studies, diversity should be also considered, in terms of geographical spread across Europe, as well as to ensure that the TRL level is met.

Impacts: Impact indicators and DNSH principle considerations – guide

- **Impact indicators**

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Use the prioritised list of indicators below to make it comparable across solutions (emissions/output, buildings - emissions per square meter heated etc., specific indicators to floor area, volume etc.); units - use international system of measure (SI).

The impact of a given solution (in view of GHG emissions reduction or energy savings for example) is in many cases difficult to quantify. If quantified impacts are available from literature/case studies, they are very context specific, and often a quantification of impact is only possible in comparison with the status quo/alternative solutions etc. Against this background, it is suggested to:

- provide a **quantification if available** and backed by a robust reference (but always be explicit about its limitations, add a caveat as needed, be explicit in case this possible impact depends on a number of other things etc.);
- provide a narrative of the expected impact if no/limited quantification is possible (still using the suggestions on the list of indicators as guidance, and backed by references);
- provide ranges;
- if the impact is generated by a package of measures rather than the standalone solution, explicitly mention this in this section

Guidance for the selection and examples of possible indicators

The general principle to follow is that the **indicator should allow for comparison across solutions** (for example emissions/ per unit of physical output, energy consumption/end-use activity, etc.) and for impact estimation by the audience based on local specificities (e.g. units of physical output). Accordingly, normalised indicators are recommended whenever this information is available. Both **indicators that describe the characteristic behaviour of the solution** (e.g., power absorption, COP) **and indicators that describe the benefit achieved by implementing the solution** as compared to meaningful comparative terms (e.g., energy savings compared to reference buildings) are welcome. As for the units, unless there is global consensus on the use of a different system, the International System of Units should be adopted.

Where a quantification is not possible, qualitative indicators may be used. However, in this case, it is strongly recommended that the selected indicator is descriptive of the impact on climate neutrality, GHG emissions reduction, or climate change mitigation (in decreasing order of preference) over other aspects.

The below list of indicators is provided as examples. Additional indicators may be used to describe the impact and efficiency of a specific solution.

- **Emissions**
  - Emissions of GHG from the production and processing of energy per unit of energy output (tons CO_2e/MWh or tons CO_2e/MJ or CO_2e/m2)
  - GHG emissions reduction (e.g., by replacing an energy-hungry system with the solution in object) per unit of energy output (tons CO_2e/MWh or tons CO_2e/MJ or CO_2e/m2)
  - GHG emissions avoidance (e.g., by removing the need for energy consumption or by reducing the trip length) (%CO_2e)
- **Energy consumption**
  - Energy consumption per unit of end-use activity (kWh/m2/y)
  - Energy savings compared to reference building (% kWh/m2/y)
  - Passenger kilometre energy intensity (MJ/pkm)
- **Cost**

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Where available, indicators related to capital requirements and operational costs can be provided (keeping a reference as this may be location specific), for instance:

- Total capital requirements per unit of energy output or installed capacity (EUR/MW or EUR/MJ)
- Total capital requirements per unit of output (EUR/unit)
- Total annual operational costs per unit of energy output (EUR/MWh or EUR/MJ)
- Total annual operational costs per unit or per energy output (EUR/unit or EUR/MJ)

DNSH – Do No Significant Harm principle considerations

Add if the research on barriers, co-benefits/negative side-effects indicates a potentially significant risk.

Table 2: DNHS considerations for each environmental objective *(source: Regulation (EU) 2020/852)*

Environmental objective	Activity to be considered significantly harm
1. **Climate change mitigation**	Any activity that leads to a significant greenhouse gas emissions on a lifecycle basis (the scope of the assessment should encompass the production, use and end-of-life phases – wherever most harm is to be expected[5]).
2. **Climate change adaptation**	Any activity that can increase adverse impact of the current climate and the expected future climate, on the activity itself or on people, nature or assets.
3. **Sustainable use and protection of water and marine resources**	Any activity that is detrimental to the good status or the good ecological potential of bodies of water, including surface water and groundwater; or to the good environmental status of marine waters.
4. **Circular economy**	Any activity that: 1. leads to significant inefficiencies in the use of materials or in the direct or indirect use of natural resources such as non-renewable energy sources, raw materials, water and land at one or more stages of the life cycle of products, including in terms of durability, reparability, upgradability, reusability or recyclability of products; or 2. leads to a significant increase in the generation, incineration or disposal of waste, with the exception of the incineration of non-recyclable hazardous waste; or c) leads to long-term disposal of waste causing significant and long-term harm to the environment.
5. **Pollution prevention and control**	Any activity that leads to a significant increase in the emissions of pollutants into air, water or land, as compared with the situation before the activity started.
6. **The protection and restoration of biodiversity and ecosystems**	Any activity that is significantly detrimental to the good condition and resilience of ecosystems; or detrimental to the conservation status of habitats and species, including those of Union interest.

[5] Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, amending Regulation (EU) 2019/2088. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32020R0852&from=EN

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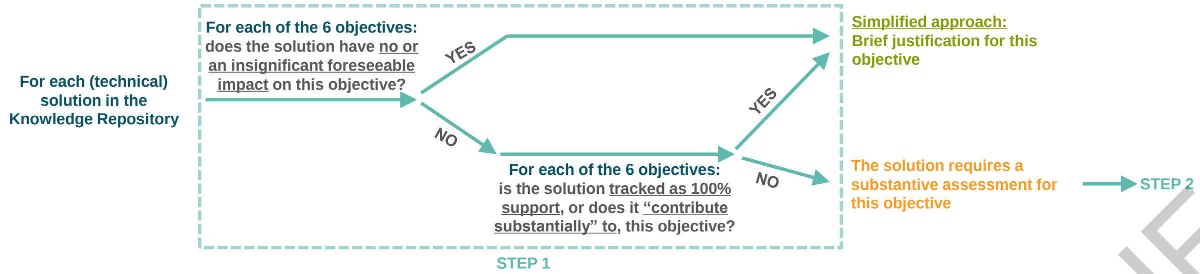

Figure 13: Pathway to check the Do No Significant Harm (DNSH) principle

Additional information from Case Studies – guide

Include information on the **timeline** for implementation, **costs**, etc. (if available, highlighting that timeline and/or costs are context-specific).

The approach here is to screen analysed case studies for specific information on implementation timeline and costs, and any other information deemed relevant for replication.

It is also recommended to check the Case Studies already available in the Knowledge Repository, and link it with the corresponding URL.

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3 Catalogue of Solutions to address GHG emissions

NetZeroCities consortium have distinguished **more than 170 solutions** addressing emissions from buildings, industry, transport, waste treatment (both solid waste and wastewater), agriculture and forestry, and, of course, energy from fossil fuels (whether from the power grid energy supply or district heating networks, or other). The solutions were classified in eight thematic areas related to such emission domains or sources (reviewed and agreed with the European Commission's Joint Research Centre- JRC).

In the next sections, each Thematic Area considered in the NZC taxonomy is depicted, with a link to the article in the Knowledge Repository (reported already in Deliverable 10.2) which makes overall sense for the thematic area and connects with all the solutions and categories within. In the following sections, just a table which structures the area in categories and the solutions within is included, together with the link to the (sub)section in which each solution is detailed in the Factsheet.

As part of the **collaboration with the JRC** (European Commission's Joint Research Centre) in this activity, they contributed to develop a number of solutions. From the list we shared with them and was agreed across the thematic areas, they selected several solutions to develop the "pink" fields, in which they were more interested. The process was then that they received the "orange" fields developed by the WP10 team in such solutions, and they developed the "pink" fields of them, while editing and improving (adding further information and so on) the part of the description and other fields already developed. This was then supervised by the RTD (Directorate-General Research and Innovation), and share with Cartif, who has the responsibility to add their content to the corresponding solution factsheets in the Knowledge Repository, and update the previous content with the changes made by JRC team. They were also added as "Authors" in such edited factsheets.

As it was a quite smooth collaboration, we knew in advance the solutions for which the JRC was going to develop the "pink" fields, and they were consequently not done in the WP10, so in this deliverable we are only reporting the work develop within the NZC – WP10 team, which can be seen completed in the NZC Knowledge Repository.

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3.1 Stationary Energy (Buildings)

- **Knowledge Repository: Stationary Energy (Buildings):** https://netzerocities.app/resource-327

Table 3: Stationary Energy (Buildings) solutions

Stationary Energy (Buildings)		Section
Building envelope solutions	Envelope insulation	**3.1.1**
	Green roof	**3.1.2**
	Green walls and green façades	**3.1.3**
	Joinery for low-energy houses or passive houses	**3.1.4**
Passive building solutions	Passive building design strategies: building orientation, passive heating and cooling	**3.1.5**
	Natural ventilation (incl. wind catchers)	**3.1.6**
Integrated solutions	Climate-smart urban agriculture	**3.1.7**
Low-carbon and sustainable building materials	Reducing embedded emissions of buildings	**3.1.8**
RES and energy-harvesting solutions	Photovoltaics	**3.1.9**
	Solar thermal panels	**3.1.10**
	Solar thermal systems with Evacuated Tube Collectors (ETC)	**3.1.11**
	Hybrid systems (PVT, PV+HP, ...)	**3.1.12**
	Geothermal energy for H&C	**3.1.13**
	Sustainable biomass and biogas technologies	**3.1.14**
Smart solutions	Building Automation and Control Systems (BACS)	**3.1.15**
	Demand management	**3.1.16**
Heat recovery solutions	Freecooling opportunities (Air-to-air heat exchangers)	**3.1.17**
	Sewage heat recovery via pump system	**3.1.18**
Sustainable and energy-efficient active solutions	Smart street lighting – Humble Lamppost	**3.1.19**
	Low-GWP heat pumps	**3.1.20**

3.1.1 Envelope insulation

- Authors: **CARTIF**
- Knowledge Repository link: **https://netzerocities.app/resource-154**

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the "orange" fields of this solution, and then it has been afterwards reviewed by JRC and completed the "pink" fields, and the Knowledge Repository content has been updated with JRC's input. So, here only the "orange" fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

Envelope insulation
Building envelope consists of all components that separate the interior from the exterior in a building, it includes the **roof, walls and floor**. The most important principle for **energy efficient construction** is a **continuous insulating envelope all around the building**, which is also key to maintain **comfortable indoor conditions.**

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Envelope insulation

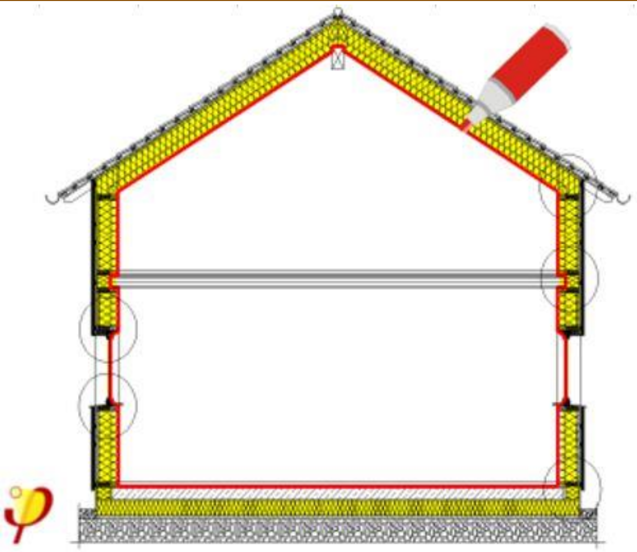

Figure from https://passipedia.org/planning/thermal_protection

Thermal insulation is a construction material with **low thermal conductivity (U-value)**, often less than 0.1 W/mK. Main industrial **insulation materials** are mineral fibre products, cellular plastic products, and plant/animal derived products.

A **thermal bridge free design** is also very important for an efficient building envelope. A thermal bridge is any discontinuity of insulation or localized decrease in insulation. An adequate building's insulation needs to consider the **airtightness** of the envelope, since a significant air infiltration degrades the benefits of the insulation used.

The overall performance of the insulation lays therefore on 3 pillars: insulating power of the materials, airtightness of their implementation and the reduction/absence of thermal bridge. The **insulation material** is more effective if **placed from the outside** (acting like a warm coat), because this way it treats thermal bridges more effectively, it preserves the **thermal inertia** of the building, as well as limits the risk of condensation in walls and the level of thermal bridges.

For the case of existing buildings (many **pre-1945 buildings**) it is important to beware of **humidity**. They were built with materials that allow **moisture** inside due to their porosity, which allows water vapor to migrate through the walls (like if the building "breathes"). For these cases, it is important not to disturb the hygrothermal balance of the walls, since the confinement of the wall promotes the degradation of the insulation and interior finishes, leading then to a weakening of the structure.

CO-BENEFITS	Expected benefits are related to **reduce the energy needs** of the building thanks to the better insulation improving building energy performance, thus leads also to a **reduction of GHG emissions**. The buildings properly insulated conduct to an **increase of comfort indoors**.
KEYWORDS	Envelope insulation is directly linked with joinery for low-energy houses or passive houses, passive building design strategies. It can form a solution bundle with positive energy building/houses, nZEBs, energy renovation or retrofitting strategies for existing buildings, etc.
EXTERNAL LINKS	Reference of the text: • https://passipedia.org/planning/thermal_protection • https://www.ctc-n.org/technologies/building-envelope-thermal-insulation • https://homeefficiencyguide.com/building-envelope/

EXAMPLES	• CITyfiED project, Torrelago District, Spain: Technical insights and video.
	• mySMARTLife project:
	  ◦ Ile de Nantes, France, multi-owner buildings retrofitting link
	  ◦ Bergedorf-Süd retrofitting project in Hamburg, Germany link

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3.1.2 Green roofs

- Authors: **RCN**
- Knowledge Repository link: https://netzerocities.app/resource-164

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the "orange" fields of this solution, and then it has been afterwards reviewed by JRC and completed the "pink" fields, and the Knowledge Repository content has been updated with JRC's input. So, here only the "orange" fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

Green roofs
An aerial view makes it is easy to recognise that buildings cover the largest portion of our cities. It also makes apparent that their roofs are perhaps one of the most underutilised spaces in our cities. Typical roofs absorb significant amounts of heat. At a city-scale, this contributes to the **urban heat island effect**, i.e. the observed higher temperature of urban environments relative to their surroundings. Building or retrofitting green roofs offers are an excellent opportunity to make buildings and cities more liveable, from an aesthetic, recreational and environmental point of view. **Green roofs** enable covering roof with vegetation, including a structure composed of three main layers (vegetation, substrate, drainage).

Different types of green roofs. Source: Iogor Bronz, urban soil institute

Three types of green roofs can be distinguished:
Extensive green roofs: technique using an elaborate culture complex of low thickness, allowing the creation of a plant cover, made up of plants of horticultural or wild origin. They have a low total thickness of 4 to 10 cm. They do not require irrigation after the establishment period.

Semi-intensive green roofs (15 to 30 cm) they have small herbaceous plants requiring moderate maintenance.

Intensive green roofs (> 30cm) with horticultural type vegetation, which can be very diverse and tall (trees).

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Green roofs	
 Green Roof (architect: agence Terreneuve) © Arnaud Boissou – Terra The benefits of are mainly related to the **thickness of the substrate**. The thicker the substrate, the better the retention and insulation properties and the more ecosystem services are provided. Green roofs can be extensive (shallow substrate) requiring lower maintenance, or intensive (greater depth) which can accommodate most types of plants, from grass up to trees in certain cases.  Blue-Green Roof in Amsterdam (source: RESILIO Project; *https://resilio.amsterdam/en/*) In terms of mitigation, green roof can reduce GHG emissions, and through the process of photosynthesis, vegetation and soil media can sequestrate and store carbon. Green roof can **reduce energy needs** for buildings cooling, due to the shading effect, the creation of a thermal mass "buffer" against daily fluctuations, and the evapotranspiration (which occur as moisture trapped in the root zone of plants and droplets in the foliage layer evaporate and dissipate).	
CO-BENEFITS	In terms of **climate resilience**, green roofs contribute to climate **mitigation** by **reducing energy needs** and increase moderately carbon sequestration. They contribute to climate **adaptation** by reducing flood risk and extreme temperatures. In terms of social, they contribute to **social cohesion** as community spaces. They can **enhance citizen participation** (e.g. in maintenance or urban agriculture). They offer education opportunities of how natural systems operate. In terms of health, they contribute to **well-being** by making cities more attractive. In terms of resource efficiency, depending on design and intended use, they contribute to **water efficiency and food efficiency**.

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Green roofs	
	In terms of **biodiversity**, green roofs, depending on design, can offer biodiversity opportunities, e.g. through **pollinator increase** and use of native species (these roofs often called brown roofs).
KEYWORDS	Green roofs are directly linked with building solutions, passive buildings and retrofitting of existing buildings.
EXTERNAL LINKS	• Youngman, A., Green Roofs: A Guide To Their Design And Installation, 2012, The Crowood Press • Mentens, 2006: Mentens, J., Raes, D. and Hermy, M. (2006) Green Roofs as a Tool for Solving the Rainwater Runoff Problem in the Urbanized 21st Century. Landscape and Urban Planning, 77, 217-226. Link • Kumar, 2005: Rakesh Kumar, S.C Kaushik, performance evaluation of green roofs and solar shading for thermal protection of buildings, Buildings and Environment, Vol.40, pp.1505-1511, 2005 • Biosolar Link • Nature4Cities, NBS multi-scalar and multi-thematic typology and associated database, 2019, pp. 325-352
EXAMPLES	• Blue-green roof in Amsterdam Link • Green roof ecosystem services in various urban development types: A case study in Graz, Austria, Urban Forestry & Urban Greening Link

3.1.3 Green walls and green façades

- Authors: **CEREMA**
- Knowledge Repository link: **https://netzerocities.app/resource-174**

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the “orange” fields of this solution, and then it has been afterwards reviewed by JRC and completed the “pink” fields, and the Knowledge Repository content has been updated with JRC’s input. So, here only the “orange” fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

Green walls and green façades
Green façades and greens walls are part of the so-called **vertical greening techniques**. Green façades are made up of **climbing plants** that cling: • directly to the facade, thanks to adventitious roots (spikes or suction cups) allowing anchoring along the facade; • along a support fixed to the façade, by rolling up or clinging to it thanks to their specialised organs (tendrils, voluble petioles); • usually made of stainless-steel cables and/or bars.

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Green walls and green façades	
  Figures: implementation of the elements of a green wall under construction at the Shopping Mall "Les Sentiers" in Claye-Souilly; and Green façade with climbing plant. When it is not possible to root the plants in the soil, they are **placed in planters**, long pots, with a substrate of at least 50cm, large enough to provide the plants with a sufficient supply of water and nutrients for their development. **Green walls (or living walls)** are plants that are rooted in a substrate attached to the façade. The green wall requires a hydroponic fertigation system, allowing fertiliser to be applied via an irrigation system. Different technologies are available: • **panel**: metal panel filled with an organic or non-organic substrate, requiring constant watering and fertilisation; • **soil cell**: cell filled with a substrate, also requiring constant watering and fertilisation; • **planter box**: planter integrated into the façade, with an organic-mineral substrate; • **felt layer**: polyamide felt placed on a PVC support serving as a rooting and retention substrate for water and minerals (requires a large quantity of water and fertilisers). In terms of **mitigation**, green walls and façades contribute very moderately, by using part of the sun's radiation for photosynthesis and by creating shaded areas on the walls, the plants allow to **reduce the temperatures inside the building**, and thus to reduce the energy needs linked to air conditioning or any other system of regulation of the interior temperature. It should also be noted that green façades **have a relatively high carbon footprint**, particularly due to the manufacturing process of the substrate which emits greenhouse gases. In terms of **adaptation**, green walls and green facades allow less radiation to be reflected towards neighbouring buildings and pedestrians. They help to improve pedestrian comfort in hot weather and to some extent reduce the urban heat island effect.	
CO-BENEFITS	**Health**: green walls and green façades improve **air quality**. They remove some gaseous pollutants (NOx, O3), which are permanently absorbed through their stomata. The particles are intercepted at the leaf surface. This interception is

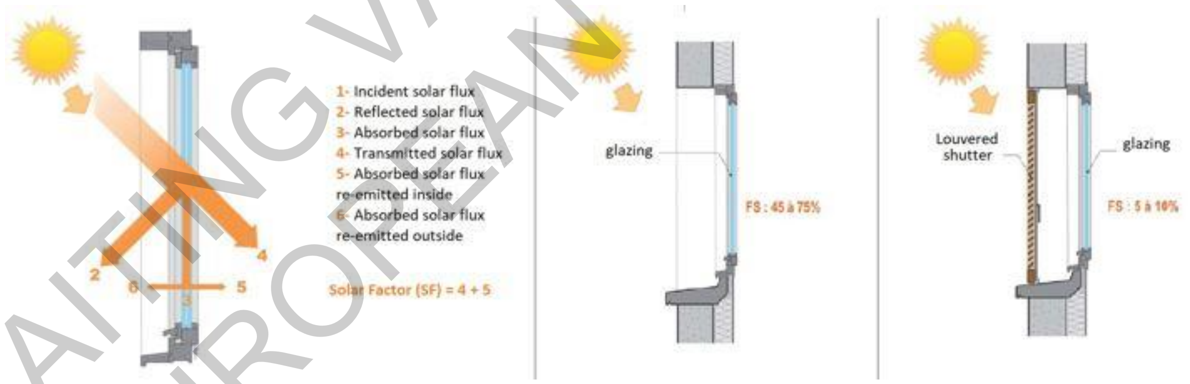
Green walls and green façades	
	temporary, insofar as these particles can be put back into the atmosphere, or even be washed away by rain. **Biodiversity**: green walls and green façades may provide a refuge for species such as insects (pollinators, spiders), snails and birds. This biodiversity depends on many parameters, such as the type of substrate used, the palatability of the foliage, the presence of berries or fruit, etc. **Well-being**: they contribute to improving the well-being of inhabitants. Even if they are sometimes only elements in the middle of highly urbanised elements, the mere sight of green walls and green facades can generate positive affects, which are beneficial to well-being.
KEYWORDS	Green walls and green façades are directly linked with other building envelope solutions, as well as building integral solutions (such as a passive building).
EXTERNAL LINKS	Reference of the text: https://www.urbangreenup.eu/solutions/green-facade-with-climbing-plants.kl
EXAMPLES	• Case Study in Genova Link

3.1.4 Joinery for low-energy houses or passive houses

- Authors: **CEREMA, CARTIF**
- Knowledge Repository link: **https://netzerocities.app/resource-184**

Joinery for low-energy houses or passive houses

Joinery is the component used to dress the openings (openings intended to let light and people circulate), i.e. doors and windows. **Windows** play an essential role in **bioclimatism**. In winter they must capture free solar gain while reducing heat loss. In summer, they must limit direct solar radiation to avoid overheating, while enable natural lighting. Therefore, joinery is often supplemented by shutters and sun protection.



Limit losses in winter: Single glazed joinery is inefficient. Performance improves significantly with double glazing, because double glazing allows to slow down the transmission of heat and thus increase the thermal resistance of your openings. The air or gas between the two panes of glass has an insulating effect and will prevent the pane inside your home from cooling down too much and too quickly. Common **double glazing** consists of 2 panes separated by an air gap 16 millimetres thick. Additional **technologies** improve performance:

- Replacement of air by **argon**
- **Low-emissive glazing**: deposit of metal oxide on internal side of one of the glazing's that lets light through and retains infrared radiation inside that allows solar gain (heat and light) to enter while preventing long-wave infrared radiation (heat from objects and walls in the room) from leaving the house.
- Classic **triple glazing**, and high-end double glazing have similar performance, and the last is lighter and less expensive.

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This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

Joinery for low-energy houses or passive houses

Summer comfort: The first precaution is to limit the entry of solar radiation when sunshine is the strongest. Properly designed and sized in relation to the seasonal course of the sun, solar shading reduces direct radiation in summer without compromising solar gains in winter. **Horizontal solar shading** is especially useful on south facades and for buildings located in the Mediterranean climate zone.

Operational aspect. Replacing a joinery can be done partially or completely:

- Completely, which implies to clear the frame of the wall.
- Partially, by placing a specially adapted frame on the old one, if this one is healthy. In case of historical or heritage interest, replacement may not be possible. Furthermore, the installation of a double window inside the building makes possible to improve both thermal and acoustic performance.

Front door is another important element of joinery. It should include an **insulating material** that has the **lowest possible thermal conductivity**. In the case of an entrance door with glazing, it is recommended to use double glazing. Anyway, it is important to have an entrance door with air tightness at the frame and sash level.

CO-BENEFITS	With efficient joinery, you **reduce risk to natural and climate hazards**: the building is more **comfortable** in winter and summer. **Energy needs** for heating and air conditioning are **reduced**. It is therefore energy bills that will decrease, which will **reduce fossil-fuel dependency** and contribute to **reduce GHG emissions**.
KEYWORDS	Joinery for low-energy houses are directly related with other stationary energy integrated solutions (mainly at building level, such as positive energy houses/buildings, nZEB, energy renovation or retrofitting of existing buildings...).
EXTERNAL LINKS	Reference of the text: • https://www.programmepacte.fr/tags/fenetre • France: http://maisons-paysannes.org/wp-content/uploads/2013/07/ATHEBA-ouvertures-dans-le-bati-ancien.pdf

Joinery for low-energy houses or passive houses	
PRE-CONDITIONS & ENABLING CONDITIONS	***Project governance and implementation modalities*** A bioclimatic design framework for the city where strategies to optimise the design of joinery can enable the passive energy design of the buildings taking into account local climate, orientations of the buildings and other factors to optimize building energy efficiency and comfort. ***Technical aspects/infrastructure*** In terms of joinery design, the framework should consider how to capture heat in the winter and prevent excess heat from entering the building in the summer. For example, in the winter, it may be important to design windows and other joinery to allow for maximum solar gain, while in the summer, shading devices or other methods may be necessary to prevent excess heat gain. The framework should also consider the orientation of the building and the specific exposures of sensitive walls to the sun: in the North hemisphere its common to limit losses in the North walls, whereas in the South walls (East and West too) the challenge is to limit the losses at the same time the solar flux is optimized according to the season. If a building is located on a classified site or has heritage interest, there may be specific requirements or guidelines for the design of joinery in order to maintain the appearance of the building. In these cases, it is important to find a balance between preserving the historical appearance of the building and optimizing its energy efficiency through modern joinery design.

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Joinery for low-energy houses or passive houses	
	Other enabling conditions include: right skills of the workforce and awareness of the citizens; energy certificates promotion; building regulations promoting joinery and passive techniques; etc. Technically speaking the framework should take into account which surfaces should be exposed or not to the sun, and how to prevent heat from entering in summer. Identify the exposures of the sensitive walls, in the North the issues will be to limit the losses by the joinery. In the south (East and West also) the challenges will also be to limit the losses, in addition to optimize the capture solar flux according to the season. It is also needed to identify if the building is located on a classified site, or of heritage interest, ...). In this case possibility to have to respect specific appearance (of old joinery for example).
CONSTRAINTS/ BARRIERS for implementation	Joinery is an element of the envelope with opaque walls, their replacements, or even their implementation in a new project, must be integrated into a global reflection of thermal improvement of the building envelope: the continuity of the insulation must be treated, for example work on the junction between wall insulation and joinery can limit thermal bridges. Humidity in homes comes largely from human activity inside (breathing, showering, cooking, etc.). As part of a renovation of the joinery, we will improve the airtightness, and thus reduce the evacuation of this humidity. So special consideration of ventilation is necessary because it allows humidity to be evacuated effectively.
INSTRUMENTS/ Processes for implementation	***User engagement for energy efficiency***: Final users need to know this efficiency in the context of their building to accept Investment (overall calculation of the energy performance of the building). ***Incentives***: Needed to stimulate construction stakeholders to invest in this technology for new and existing buildings. ***Data strategy***: Needed to collect data on energy savings and GHG emissions.
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	In renovation, a bad change of joinery can cause humidity problems that degrade the building and air infiltration that limits energy performance. To ensure good summer comfort it is recommended to equip the windows with horizontal masks. Without reflexion it's possible to have thermal discomfort and more climatization consumption. When the masks are correctly sized, it is possible to significantly reduce direct radiation in summer without compromising solar gains in winter. They are especially useful on south facades.
IMPACTS (Indicators & DNSH)	***Energy savings*** Energy savings due to the use of joinery in buildings depend on the climate (therefore, location), on the type of joinery and on the number (generally joinery represents a small part of losing surface on building). Indicative numbers are: triple glazing saves 1-1,5 times more energy than double glazing, which saves 2-3 times more energy than single glazing. ***GHG emissions avoidance (removing energy consumption in buildings)*** Emission reductions due to the use of joinery in buildings depend as before on the climate, the type of joinery, the number, but above all on the energy used in the building. The more carbon-intensive the energy used (gas for example), the greater the reduction in emissions will be with good joinery.

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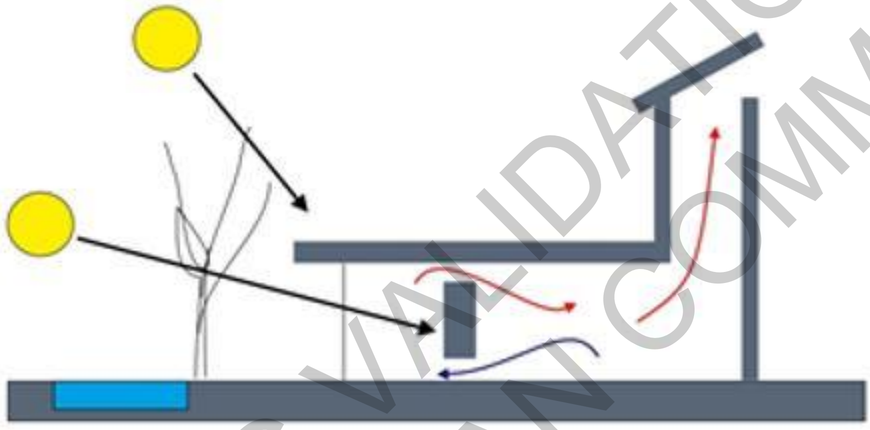
3.1.5 Passive building design strategies: building orientation, passive heating and cooling

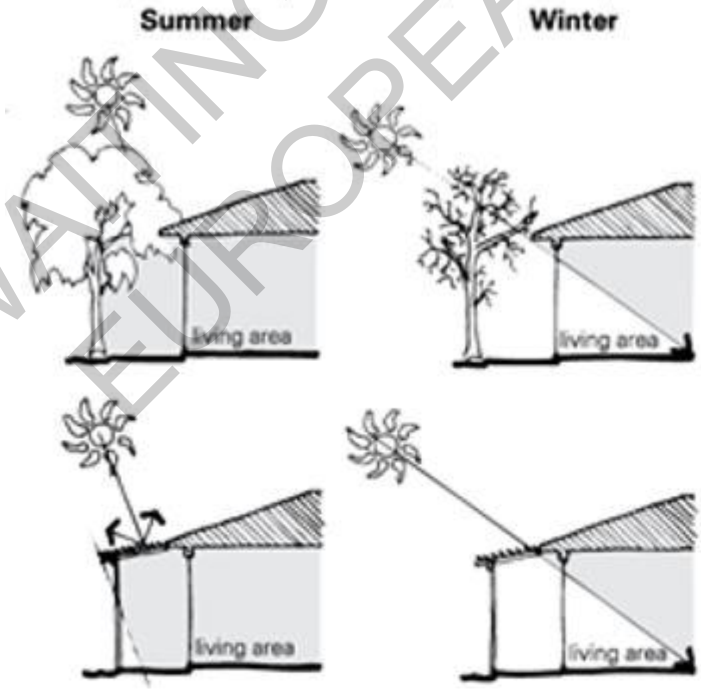
- Authors: **CARTIF**
- Knowledge Repository link: https://netzerocities.app/resource-194

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the "orange" fields of this solution, and then it has been afterwards reviewed by JRC and completed the "pink" fields, and the Knowledge Repository content has been updated with JRC's input. So, here only the "orange" fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

Passive building design strategies: building orientation, passive heating and cooling
Passive design strategies are based on using **layout, fabric and form** to reduce or remove mechanical cooling, heating, ventilation and lighting demand (allowing **downsizing the active energy systems**). Passive design should create buildings that consume less energy, including **passive heating, passive cooling and natural ventilation**, while considering **location** (climate), **orientation**, massing, **shading**, material selection, thermal mass, **insulation**, **internal layout** and the **positioning of openings** to allow the penetration of **solar radiation, daylight and ventilation**.



Passive building design. Source: https://www.designingbuildings.co.uk/wiki/Passive_building_design



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Passive building design strategies: building orientation, passive heating and cooling

Shading devices for north-facing openings. Source: https://www.yourhome.gov.au/passive-design

Building **orientation** is a key aspect for passive design, while taking into account the **climate**. The most successful energy-efficient designs are **facing south or north** to allow better solar energy management and have best quality daylighting. Building **shape** is also very relevant in the design, an elongated and narrow plant (with south or north facing façade) that allows for more of the building to be daylit and take advantage of sunlight.
Passive heating is to capture heat from the **sun** inside the building, and using **thermal mass, heat flow and insulation** effectively to store, distribute and retain the heat. **Thermal mass** is the ability of a material to absorb, store and release heat, these are typically heavyweight construction materials like concrete, brick and stone.
Passive cooling is to use design to reduce heat gain and increase heat loss. Main methods are to use shading and thermal mass in summer, as well as to **design openings** to allow good ventilation. Shading can either be operable (external **louvres**, blinds and **deciduous trees**) or fixed (e.g. eaves, **overhangs**, fences and evergreen trees).
Passive design strategies can be also rated across **standards**, such as **PassivHaus (Passive House), BREEAM, LEED or WELL**.

Standards for passive design.

CO-BENEFITS	Expected benefits are related to **reduce the energy needs** of the building thanks to the better insulation improving building energy performance, leading to a **zero GHG emissions**. Other benefits are related to **high comfort indoors** (humidity, temperature and ventilation), related to **healthier and more attractive lifestyles**; while **enhancing attractiveness of the city**, as well as leading to **low future maintenance costs** due to up-to-date and high-quality materials used.
KEYWORDS	Passive design strategies are related to envelope insulation, joinery for low-energy houses or passive houses, and natural ventilation strategies. It can form a bundle of solutions with other building integrated solutions (positive energy houses, nZEB...).
EXTERNAL LINKS	Reference of the text: • https://www.metalarchitecture.com/articles/passive-design-strategies • https://www.designingbuildings.co.uk/wiki/Passive_building_design • International Passive House Association: https://passivehouse-international.org/index.php Standards: • Passive House Institute: https://passivehouse.com/ • BREEAM (Sustainable Assessment Method): https://www.breeam.com/ • LEED rating system: https://www.usgbc.org/leed • WELL certified: https://www.wellcertified.com/

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3.1.6 Natural ventilation (incl. wind catchers)

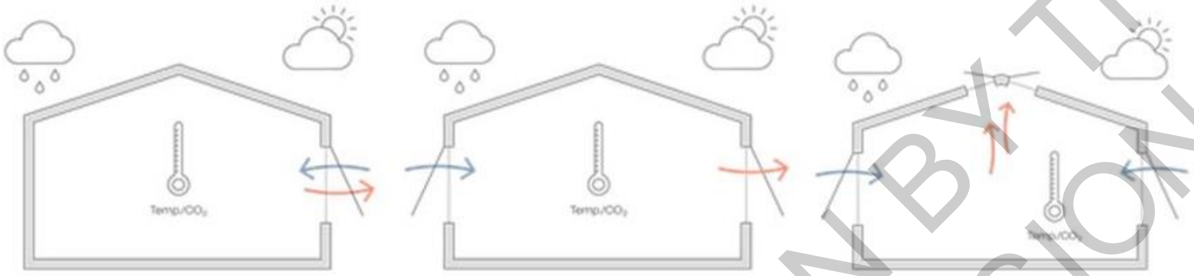
- Authors: **CARTIF**
- Knowledge Repository link: **https://netzerocities.app/resource-246**

This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

Natural ventilation (incl. wind catchers)

Natural ventilation (or passive ventilation) makes use of natural forces, such as wind and thermal buoyancy, to circulate air to and from an indoor space in order to maintain **good indoor air quality**. These ventilation systems work to regulate the internal air temperature as well as bring fresh air in and send state air out. This is largely achieved through the opening and closing of windows and vents which act as a source of air as well as exhaust.

Ventilation is essential to replace stale air with fresh air. Without proper ventilation, buildings become susceptible to stagnant air, where bacteria and carbon make the indoor more polluted than the air outside.

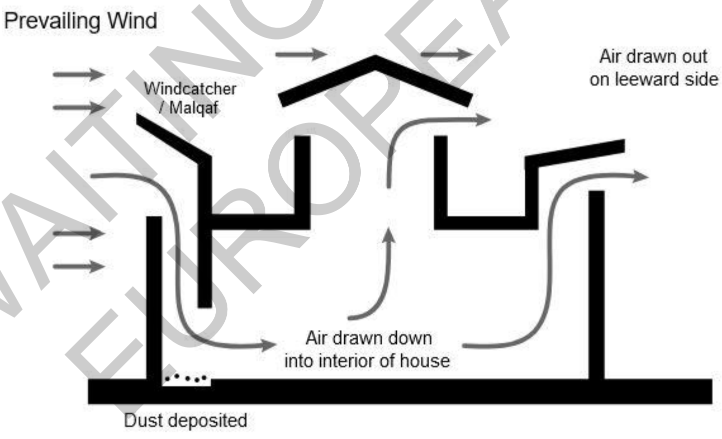


Natural ventilation: single-sided ventilation, cross ventilation and stack ventilation. Source: https://www.windowmaster.com/

Natural ventilation strategies depend on the design of the building, the internal thermal loads, and the positioning of openings (usually windows). Natural ventilation can **be single-sided ventilation, cross ventilation** (the most effective method of wind ventilation) or **stack ventilation**, depending on the characteristics of the building.

Passive ventilation works in a number of ways, including **wind-driven ventilation** (arising from different pressures created by winds around a building), **buoyancy-driven ventilation** (created by forces resulting from the temperature difference between the interior and exterior of a building), and **night cooling** (a passive cooling method, driven by the natural driving forces of the wind and/or thermally –stack- generated pressures; the heat absorbed by a building's exposed thermal mass during the day is released to the indoor air at night, after which it is purged by night ventilation).

Additionally, for natural ventilation **windcatchers** (traditional in Persian architecture) can also be used, usually in the form of small towers on top of buildings which draw air from outside into a building, thus providing natural ventilation in hot, arid and humid areas.



Windcatcher (for natural ventilation). Source: https://www.wikiwand.com/en/Windcatcher

CO-BENEFITS	Expected benefits are related to reduce the needs of mechanical ventilation, which leads to a **reduction in the energy needs**, as well as to a **reduction of GHG emissions**. It also contributes to **improve air quality indoors**, and it is related also to **healthier and more attractive lifestyles**; while leading as well to **low future maintenance costs** due to the lower need of mechanical systems.

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Natural ventilation (incl. wind catchers)	
KEYWORDS	Natural ventilation is directly linked to passive building design strategies (https://netzerocities.app/resource-194), as well as to other integrated solutions in buildings, e.g. joinery for low-energy houses (https://netzerocities.app/resource-184), envelope insulation (https://netzerocities.app/resource-154), green roof (https://netzerocities.app/resource-164), green walls and green façades (https://netzerocities.app/resource-174), climate-smart greenhouses (https://netzerocities.app/resource-276), Building Automation and Control Systems (https://netzerocities.app/resource-758), etc.
EXTERNAL LINKS	***Reference of the text:*** • https://www.windowmaster.com/expertise/natural-ventilation-and-mixed-mode-ventilation/passive-ventilation/ • https://greenhome.osu.edu/natural-ventilation • Windcatcher: https://www.designingbuildings.co.uk/wiki/Windcatcher
EXAMPLES	• City of Glasgow College (BREEAM Excellent building), architectural project, UK • HouseZero, Harvard Center for Green Buildings and Cities (renovated building), CGBC Headquarters, UK • UCL Student Centre at Gordon Street, London, UK, architectural project • MECD – Manchester Engineering Campus Development, UK. Renewal of one of the UK's most large-scale higher education projects. • Augusta University Cancer Research Center, Georgia, USA. M. Bert Storey Research Building. Two building additions into the overall campus scheme • Clayton Heights Community Centre, Surrey, British Columbia, Canada. Passive House project not residential building, project. • Rocky Mountain Institute Innovation Center, Basalt, Colorado, USA. Green building design techniques, net-zero energy building, project.

Natural ventilation (incl. wind catchers)	
PRE-CONDITIONS & ENABLING CONDITIONS	***Climate and geography:*** External conditions such as temperature, relative humidity and air quality will affect the potential for implementing natural ventilation in buildings. This generally means that **extreme climates** with high external air temperature and relative humidity have a **lower potential** to design with natural ventilation. The role that building design plays in the potential for natural ventilation, whether for new or existing building, is also essential. In **temperate climates** (as in Denmark, Norway, Germany, Switzerland, and most of the UK), the natural ventilation works quite well.… In climates with higher external temperatures or relative humidity, **mixed mode ventilation (or hybrid ventilation)** is an effective approach to get the best benefits of natural ventilation without compromising indoor air quality. In this mixed mode ventilation approach, the natural ventilation can be switched on or off depending on the outdoor conditions. This helps to ensure that the building performance requirements are met for both optimal comfort and energy savings. With respect to the windcatchers, they have limited application in regions with very low wind speed. ***Urban form and layout:*** External elements such as trees, adjacent buildings or other structures need to be considered since they may obstruct the wind. ***Technical aspects/ infrastructure:*** Almost all buildings can make use of passive ventilation, especially office buildings, schools, theatres and hospitals. Buildings should be **oriented** so that the windward wall is perpendicular to the summer wind (check out the wind rose map to determine the local prevailing wind direction). Thus, passive ventilation is easier to implement in **new constructions**, but it is also possible to integrate it in existing buildings, and

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Natural ventilation (incl. wind catchers)	
	to combine it with other systems already in place. The new passive system will complement the existing one to take advantage of the use of natural forces.
CONSTRAINTS/ BARRIERS for implementation	Several **factors affect** natural ventilation (such as prevailing wind speed and direction, surrounding environment, building footprint and orientation, outdoor temperature and humidity, size, location and opening of windows), and **proper design is key** for natural ventilation to work and be effective. As far as **windcatchers are concerned**, they may have some **limitations**: they may allow small animals, birds or insects to enter; the head of windcatchers is fixed and does not rotate with the direction of air flow; in areas with very low wind speed they have limited application.
INSTRUMENTS/ Processes for implementation	Instruments related with the **improvement of Energy Efficiency in buildings**, as it is means to reduce building's energy consumption by relying on natural forces, e.g.: • User Engagement for Energy Performance Improvement: https://netzerocities.app/resource-14988 • Loans for Energy Efficiency (EE): https://netzerocities.app/resource-1648 • Blended finance for Energy Efficiency (EE): https://netzerocities.app/resource-1658 • Building Renovation Passport (BRP): https://netzerocities.app/resource-1748 • Turnkey Retrofit Service: https://netzerocities.app/resource-1843 • Analysis of City/ (Building) circularity: https://netzerocities.app/resource-1873 • One-stop-shop for building renovation: https://netzerocities.app/resource-1913 • User Engagement for Energy Performance Improvement: https://netzerocities.app/resource-1498
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	Natural ventilation is often associated with the manual opening and closing of windows to renew and cool the indoor environment. While this is true, it is also possible to intelligently automate roof and facade openings to make life easier for the building occupant and to maintain the security of the building. If natural ventilation is carried out **manually**, it can pose a threat to the security and integrity of the building. If an occupant leaves a window open, someone could illegally enter the building or rain could damage the interior. It can also contribute to uncomfortable draughts in the wintertime if not done properly. This **control is automatic** in some cases, especially in mixed **mode ventilation systems**, which use sensors to monitor indoor temperature, CO_2 levels, and humidity, as well as outdoor conditions. Based on this data, the system automatically selects natural ventilation or mechanical ventilation depending on which system is more optimal to use.
IMPACTS (Indicators & DNSH)	For monitoring in a specific building: • **Energy savings** compared to reference building (without passive ventilation) or building energy consumption before the implementation of ventilation passive systems. [% of $kWh/m^2/year$] • **GHG emissions reduction** according to previous energy savings [% of CO_{2e}]
	DNHS, substantive assessment for: **Climate change mitigation**: take into account that the implementation of the natural ventilation systems or mixed mode of ventilation system do not lead to a significant greenhouse gas emission on lifecycle basis.

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3.1.7 Climate-smart urban agriculture

- Authors: **METABOLIC**
- Knowledge Repository link: https://netzerocities.app/resource-276

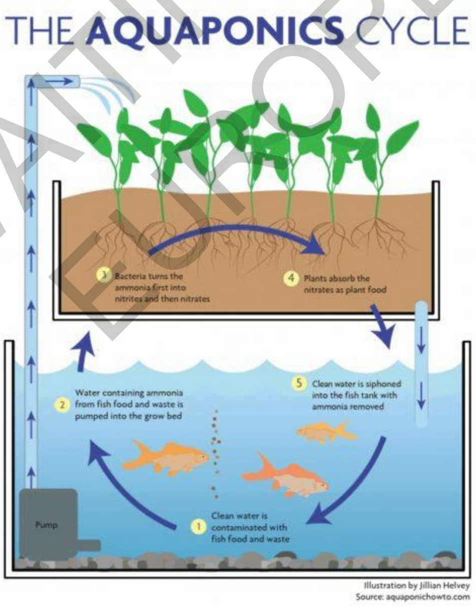
Climate-smart urban agriculture

Climate-smart greenhouses are making use of innovative solutions to adapt to changing conditions in cities as a consequence of climate change. They allow for **food production** in densely-populated urban areas with a minimal environmental footprint, **using less resources** (energy, water) **and space** than traditional greenhouses and adapting to changing conditions such as rising temperatures or risks of heavy rains.

Source: https://www.metabolic.nl/news/advancing-aquaponics-metabolic-greenhouse/

Vertical planting platforms help to use space as efficiently as possible. Special design features allow for the reuse of water. **Innovative drip irrigation systems**, for example, can save up to 90% of water compared to conventional greenhouses and are especially suitable for vertical farming techniques.

Another innovative solution to reduce water usage is an **aquaponics system** which can feed a large vertical planting wall in a connected greenhouse. It combines fish and vegetable production in a closed-loop system. Fish excreta provides nutrients for the plants, and the plants filter the water for the fish to live in. The system is self-contained with minimal impacts on the surrounding environment. It can produce food with 10% of the land area and 5% of the water usage needed for conventional agricultural production.



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Climate-smart urban agriculture	
Using **innovative cover materials** to construct greenhouses can be useful in the process of climate change adaptation and help with ventilation and shading. **Aluminium-coated cloth-netting** is a good example: It is breathable and helps to reflect sunlight, reducing the temperature in the greenhouse. Other materials are specifically designed to counteract the increasing risks of insect invasion.	
CO-BENEFITS	Climate-smart greenhouses promote a **proximity economy** as they facilitate the growth of edible plants in urban environments and therefore decrease the need for imports. Furthermore, as locals can get involved in the maintenance of such greenhouses, they also contribute to **enhanced citizen participation, connectivity, and community**. Some greenhouse projects also offer educational activities, that promote **improved access to information**, **raised awareness/behavioural change**, and **increased skill development**. At the same time, the harvested plant-based foods help to promote a **healthier and more attractive lifestyle**.
KEYWORDS	Climate-smart greenhouses are related with other solutions at building level, as well as with Nature-based solutions in buildings.
EXTERNAL LINKS	• Aquaponics Greenhouse at De Ceuvel, Amsterdam: Link • Cité Maraichère, Romainville: Link • Sunworks, New York City: Link • Floating Greenhouse, Naaldwijk (NL): Link

Climate-smart urban greenhouses	
PRE-CONDITIONS & ENABLING CONDITIONS	***Funding and financing:*** Access to EU/public funding can be crucial to support the initial investment required to develop and/or purchase R&I solutions for urban climate-smart agricultural solutions. ***Economic and social context:*** Training for local farmers, researchers, employees, and students to local agricultural skills and innovation potential in the field of climate-smart urban agriculture. For example, automation engineers and software engineers are required to install the climate stations, lighting system, and water recycling system.
CONSTRAINTS/ BARRIERS for implementation	***Equipment costs*** put a lot of pressure on the budget. Most climate-smart urban farms need expensive equipment such as climate controls, shelving units, LED lights, water lines, computers, etc. Nevertheless, the cost of indoor agriculture equipment is expected to drop dramatically as indoor agriculture becomes more popular and the number of vertical farms increases. ***Lack of knowledge and expertise:*** Many greenhouse operators may not be familiar with the latest technologies and practices used in climate-smart greenhouses and may not have the expertise or resources to implement and maintain these systems. ***Space and infrastructure:*** Even though greenhouses can be small, and the essence of vertical farming is that it takes up less space, spaces in cities are scarce and expensive. Finding a space and setting up an agricultural infrastructure for climate-smart urban agriculture is therefore hard and will most likely need (financial) support from a municipality. ***Market barriers:*** Greenhouse operators may face challenges in accessing markets for their products, particularly in cases where climate-smart greenhouses produce crops that are not in high demand or are not well-known to consumers. In addition, greenhouse operators may face competition from imported produce, which may be cheaper or more readily available.

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Climate-smart urban greenhouses	
INSTRUMENTS/ Processes for implementation	• Training: e.g. Specialisation at Wageningen University in Greenhouse Horticulture • Voluntary measures with stakeholders • Taxation: E.g. New Zealand's plan to tax cow and sheep burps might drive farmers to more sustainable modes of agriculture such as climate-smart greenhouses.
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	***High running costs:*** If you run a climate-smart farm completely indoors, 100% of the light must be artificially fed. So, the cost of electricity, even with LED lamps, will be very high. ***Technological failures*** could lead to major problems: Another problem with climate-smart farming is its heavy dependence on technology. If the irrigation system or electricity fails, this can cause massive damage to the plants. ***People in rural regions could lose their livelihoods:*** In many rural regions, people are still heavily dependent on conventional agriculture. If we were to switch completely to alternative modes of agriculture, it will bring about drastic societal/cultural change. On the other hand, these people can then be trained to be part of the transition to more sustainable modes of agriculture.
IMPACTS (Indicators & DNSH)	Water savings compared to conventional greenhouses; soil pollution of fertilisers used in conventional agricultural processes.
	DNSH: ***The protection and restoration of biodiversity and ecosystems*** These climate-smart urban agricultural systems are often farms that are set up inside a greenhouse/old warehouse/container. This makes them inaccessible to bees and other pollinators which could not only cause a lack of cross-pollination of the crops within the greenhouses but also outside. Poor pollination rates diminish the variety of the crops which results in poor fruit sets and the production of small and misshapen fruits. On the long run this could be detrimental to biodiversity and the resilience of ecosystems. ***Climate change mitigation*** Since climate-smart greenhouses are often run inside and need artificial lightning to feed the plants, a large supply of energy is needed (which can also cause light pollution). If this energy is does not come from renewable sources but from coal for example the sustainability rate of the climate-smart greenhouse will drop significantly.
Additional information from CASE STUDIES	Postscapes smart greenhouses: Smart Greenhouse Remote Monitoring Systems GrowUp: Vertical farming Hydroponics: The hydroponic system is based on the growing system by which water is provided to the plant while the plant does not grow in the full soil. Infarm: Their advanced farming system (vertical farming) decouples food production from negative impacts on our ecosystems and sets a foundation for a more sustainable, efficient and environmentally friendly food system. Container farms: Pre-designed vertical farms - Is a fast, straightforward solution for growing edible flowers, herbs, lettuce, microgreens and other leafy greens.

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3.1.8 Reducing embedded emissions of buildings

- Authors: **METABOLIC**
- Knowledge Repository link: **https://netzerocities.app/resource-286**

This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

Reducing embedded emissions of buildings

The built environment makes up almost a third of global greenhouse gas emissions and the **embedded emissions of materials** used in **construction** are contributing greatly to this. **Concrete** alone is responsible for 4 to 8% of the world's CO_2. **Circularity** in the built environment and the use of **bio-based materials** can play a significant role in reducing cities' carbon emissions.

Schoonschip: A sustainable floating neighbourhood. Source: https://www.metabolic.nl/projects/schoonschip/

Concrete that already exists in our urban environments can be **reused** after being removed from buildings, for example as a foundational layer underneath roads. However, urban mining alone will not suffice to build sustainable cities. Based on research by Metabolic and the EIB, it can facilitate roughly 30% of the materials needed to build the cities of tomorrow.

Bio-based materials, which are derived from renewable organic matter (biomass) of plants or animal origin, provide an alternative to concrete. These materials include woods, hemp, straw, cellulose wadding, or recycled textiles. **Bricks** made from compressed earth can offer a climate-smart alternative to traditional bricks, as they do not require baking and therefore have a low energy footprint. They also provide an opportunity for cities to adapt to rising temperatures, as the compressed soil helps to regulate humidity and capture heat which is slowly released at night.

CO-BENEFITS	Building with bio-based materials and reducing the use of concrete in construction can significantly **reduce GHG emissions**. Another co-benefit is the significantly **reduced energy needs**, when comparing the production of bio-based materials with concrete. The use of materials such as wood and bamboo as opposed to traditional concrete also **enhance the attractiveness of the cities** and can reduce hot spots/urban heat islands in the city, which are often the consequence of building with concrete.
EXTERNAL LINKS	• Mjösa Tower (Mjøstårnet): Link • Schoonschip (Amsterdam): Sustainable floating neighbourhood in Amsterdam making use of sustainable bio-based materials, Link • Compressed Earth Blocks (Senegal): Link • Ibstock Place School (London): Link

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Reducing embedded emissions of buildings	
PRE-CONDITIONS & ENABLING CONDITIONS	***Project governance and implementation modalities*** Collaborative development of innovative architecture solutions (that include embedded emissions in their design) needs to involve not only architects and constructors, but also experts that focus on refurbishment of buildings, life cycle assessment (LCA), and stakeholders that include circular business models (e.g. a company that uses recycled concrete). ***Technical aspects/infrastructure***

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Reducing embedded emissions of buildings	
	In order to reclaim materials from waste generated by cities, especially construction and demolition waste, demolition experts need to be trained in the deconstruction principles. In addition, a recycling centre where construction and demolition waste can be gathered needs to be realized (for example https://newhorizon.nl/urban-mining/ and https://www.buurmanutrecht.com/). ***Funding and financing*** Access to EU/public funding and innovation procurement can further incentivize the development of R&I solutions for using alternative materials for buildings that have reduced embedded emissions. ***Policy and regulatory/legal framework*** Bans and/or restrictions on the use of materials with high embodied emissions (e.g. VAT reductions for refurbishment, to encourage re-use ahead of re-build). Incentives to use bio-based materials and materials from urban mines such as tax reductions on these types of materials.
CONSTRAINTS/ BARRIERS for implementation	***Costs*** A lot of bio-based materials are rather costly as it takes some time to produce them and/or they haven't been scaled up yet for public use. In addition, harvesting and refurbishing/remanufacturing of secondary materials from demolition/building sites is usually more expensive than virgin material. ***Regulations*** The difficulty of acquiring certifications for the reuse of secondary materials I.e., to be able to reuse steel beams in new construction, they need to get certified again to guarantee their structural integrity. This is not only time consuming but also a complicated process.
INSTRUMENTS/ Processes for implementation	***Training***: e.g. start incorporating bio-based materials in schools/courses for constructors. ***Regulations*** for durability, reparability and recycling in public procurement ***Material passports***: Madaster is the online library of information on materials and products. For registered buildings and infrastructure objects, our platform provides insight into the materials and products used and their location, as well as their impact on circularity and the environment. ***Certification and labelling*** ***Taxation***: I.e. virgin material tax or shifting tax from labour to material. ***Bans or restrictions*** on single use or non-recyclable materials ***Green Public Procurement***: Sustainable tendering requirements for new construction
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	The main drawback of using bio-based materials is the uncertainty of the amount of biomass to create a real supply chain. This causes the following uncertainties: • increase competition between different bio-economy sector (biofuel vs construction) and between different objectives (forest productivity vs biodiversity conservation). • Add pressure on already fragile ecosystems to match the scale of the demand. Add pressure on sustainable sourcing/practices that may not match the scales needed.
IMPACTS (Indicators & DNSH)	Type of material used in buildings, Percentage reused material
	• Mushroom Tower pavilion in New York at the Museum of Modern Art: The Living, in collaboration with Ecovative, of Green Island, New York, have developed a special biodegradable brick made of agricultural by-products, namely chopped up corn stalks, mixed with mycelium mushrooms. • Cuerden valley visitor centre: was built with straw, timber, and gravel-filled tyres. As well, it was designed so that it could be built by volunteers from the park trust, saving the park in the region of £100,000.

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This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

3.1.9 Photovoltaics

- Authors: **TNO**
- Knowledge Repository link: **https://netzerocities.app/resource-388**

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the "orange" fields of this solution, and then it has been afterwards reviewed by JRC and completed the "pink" fields, and the Knowledge Repository content has been updated with JRC's input. So, here only the "orange" fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

Photovoltaics

Solar photovoltaic (PV) systems convert solar irradiation into electricity. Various types of solar conversion technologies are currently on the market, varying in terms of costs and efficiency. Examples are **crystalline and multi-crystalline silicon PV (mainstream technology)**, as well as thin film PV (less common). More efficient technologies with bifacial modules are used for different applications e.g. with higher albedos or vertical east-west applications to offer a wider period of power generation that better matches typical load profiles.

Photovoltaics in parking lots[1]

Solar ponds – floatvoltaics [2]

Photovoltaic road Surface [3]

Photovoltaics in roads [4]

Building integrated photovoltaics [5]

Organic photovoltaics – in a bench [6]

Figure: different types of photovoltaic options (see "external links" for more information on each of them).

The solar modules generate direct current (DC), which might be used for off-grid applications, combined with an electricity storage system (battery). Off-grid systems are considered niche markets where different pricing mechanisms occur. Mostly grid-connected systems are used, where DC from the modules is converted to alternating current (AC).

Several solar PV system types exist: household rooftop systems (typically 2-10 kWp, on sloped or flat roofs), large rooftop systems (reference size 250 kWp, generally flat), multi-MW rooftop systems (reference size 5 MWp, flat). The next-generation **panels and foils lend themselves to versatile integration in a living environment** with colour, size, shape, and weight variations. For instance, by mass customization technology, PV functionality can be integrated into numerous products in the building envelope, such as facades and roofs, and also **into multiple surfaces (roads, benches, etc.)**. PV semi-fabricates can be produced on customer demand (e.g. industry) to incorporate solar PV functionality in their own products and thus no longer be dependent on the standard solar panels.

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Photovoltaics

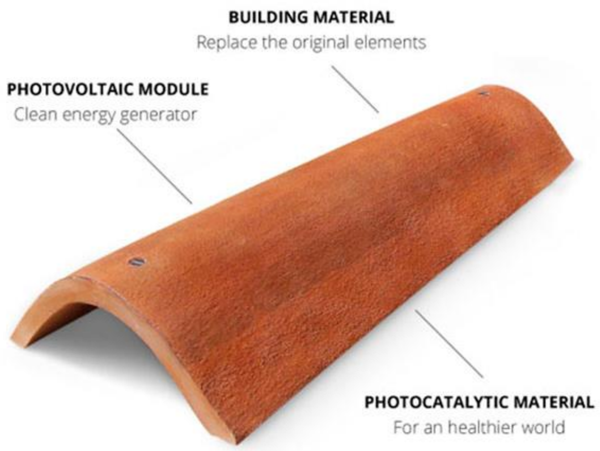

Figure: Photovoltaic tiles (applied in Evora - good fit for heritage building renovation).

CO-BENEFITS	By changing the PV supply chain and adding a semi-fabricate producer local business will be boosted and innovative mass-produced **integrated products will improve land use management by minimizing the need for land use**. Overall PV **reduces GHG emissions** while increasing the amount of PV power will increase access to **clean, affordable, and secure energy**. PV installations are linked with district-scale projects such as Positive Energy Districts or Energy Communities, as PV is the easiest technology to install. If PV is applied **in an energy community it can help to enhance citizen participation and a sharing economy.** In **PEDs PV allows for achieving a positive energy balance** (i.e. more energy produced than what is consumed) whereas in energy communities it allows to **share of the energy among the neighbours and provides social benefits:** in Crevillent an energy community run by PV allows to **reduce the cost of energy,** and also, with the energy reimbursed, **provide loans for new projects** or for scholarships to members of the community.
KEYWORDS	Direct links with Solar road, Floating Solar pontoons, Positive Energy Districts (PEDs)/ Sustainable Positive Energy Neighbourhoods (SPENs). It can form a bundle with (Nearly) Zero Energy Buildings ((N)ZEB), Positive Energy Buildings (PEB), Energy Communities/Renewable energy communities / Citizen energy communities. They can be financed by crowdfunding, or one-stop shops (e.g. OurPower, or Messukeskus), among others. They boost local business and social innovation.
EXTERNAL LINKS	[1] PV Parking lot: https://www.sens-energy.com/en/pv-carport/ [2] PV solar pond: https://www.intergia.es/en/portfolio/aguaron-floatingpv-pumping [3] PV Road: https://www.eltis.org/discover/news/electric-roads-innovative-pilot-projects-launched-sweden-and-netherlands [4] PV highways: https://www.pv-magazine.com/2020/09/01/photovoltaics-for-highways/ [5] Building integrated photovoltaics - BIPV: https://energypedia.info/wiki/Building_Integrated_Photovoltaics_%28BIPV%29 [6] Organic photovoltaics: https://ec.europa.eu/research-and-innovation/en/horizon-magazine/lightweight-bendy-cheaper-promise-organic-solar-panels Image credit - ARMOR/GerArchitektur [7] Photovoltaics in heritage buildings: • Video explaining the case of Evora https://www.youtube.com/watch?v=I7qI88A5ZJQ • Factsheet about PV in glass (1st page), PV canopy (page 5), PV skylight (page 11), roof (page 13): https://pocityf.eu/wp-content/uploads/2022/12/ETT1_all.pdf

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Photovoltaics	
	Other interesting resources: • https://youtu.be/bUu5q0vK0uw • https://energy.nl/data/solar-pv-rooftop-15-kwp-1-mwp-oriented-south • https://energy.nl/data/solar-pv-rooftop-1-mwp-oriented-south • https://energy.nl/data/solar-pv-rooftop-1-mwp-oriented-east-west • https://iea-pvps.org/wp-content/uploads/2021/04/IEA-PVPS-T13-14_2021-Bifacial-Photovoltaic-Modules-and-Systems-report.pdf
EXAMPLES	PV can be installed in many ways: • solar canopies: in highways, for parking lots, or for the main square for neighbours to enjoy some shadows (like in Crevillent). • solar ponds: 6.3MW on the Queen Elizabeth II Reservoir, near London. • solar parking lots (like in Florida or Zaragoza) • as a way to provide shading in cities (through organic photovoltaics in Tel Aviv, structures like in Madrid, solar trees in Germany). To promote its installation different incentives can be used: • reduction of municipal taxes for collective self-consumption installations (like in Sant Cugat). More details are here. • through funding schemes (e.g. Finland) • public-private partnership (like in Energy Smart Aland), etc. When there is no space, solar parks outside city boundaries can be installed (e.g., the community-funded solar park in Oxfordshire or the brownfields solar fields in New York City, Philadelphia, or Chicago), but even heritage cities like Evora are making strong efforts to integrate photovoltaic systems in their protected buildings, using transparent or ceramic innovative photovoltaics to produce electricity inside the city.
PRE-CONDITIONS & ENABLING CONDITIONS	As pre-conditions for speeding up PV implementation, a good policy framework is needed: see PV policy framework of Spain here.

3.1.10 Solar thermal panels

- Authors: **REGEA**
- Knowledge Repository link: **https://netzerocities.app/resource-438**

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the "orange" fields of this solution, and then it has been afterwards reviewed by JRC and completed the "pink" fields, and the Knowledge Repository content has been updated with JRC's input. So, here only the "orange" fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

Solar thermal panels
Solar thermal technologies convert sunlight directly into heat. Solar thermal systems vary according to collector type and mounting, storage volume, control strategy, and system configuration. The generated heat is used for domestic hot water heating, space heating, or process heating, and the solar systems are designed to provide the right temperature needed for the application. **Since solar irradiation is an energy source varying daily and seasonally, usually a backup heater (an electric resistance, heat pump or biomass boiler)** is included to provide the user with a secure heat supply. The most common types of collectors are **flat plate (FPC) and evacuated tube collectors (ETC).** While ETC collectors do have a market share in China of 90%, **FPC collectors are dominating the European market (See solar heat in building sector).**

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Solar thermal panels

Building integrated solar thermal – flat plate collectors [1]

Evacuated tube collectors - ETC [2]

Figure: shows Building integrated solar thermal –flat plate collectors [1], and Evacuated tube collectors - ETC [2]

Lately, a new solution to using existing solar thermal technology has emerged called **building-integrated solar thermal** (BIST). BIST systems are one of the subgroups of solar building envelopes and **can be integrated both into facades and roofs.** This means that the BIST is integrated into the façade, **with no air gap**, while conventional solar thermal collectors have an air gap between the collector and the rest of the building envelope. That gives BIST a wide range of solutions in architectural design features, exceptional applicability, and safety in construction, as well as additional energy production, and **improvement of the insulation and overall appearance of buildings.** Although the solar yield of BIST installed into facades is lower than the ones installed on sloped roofs, this solution creates the possibility of additional solar potential in high-rise buildings.

CO-BENEFITS	Solar thermal panels are **clean, affordable, and secure energy.** Their implementation **reduces GHG emissions** and therefore **improves air quality.** BIST may increase the **technological readiness** of solar thermal, as well as enhance the **attractiveness of the cities.** Applying solar thermal panels **boosts local business and increases employment rates and jobs.**
KEYWORDS	Solar thermal panels are linked to: evacuated solar thermal (ETC), thermal storage, on-site and nearby renewable energy generation (heat/cold), flat plate collectors (FPC), domestic hot water (DHW), space heating, improved architectural design. It can form a solution bundle with: Joinery for low-energy houses or passive houses. Projects can be funded by combining Public & Private Capital, Creating Blended Financing Structures, and Identifying Opportunities and Solutions for Improvement.
EXTERNAL LINKS	Interesting external links: • https://publications.jrc.ec.europa.eu/repository/handle/JRC118312 • https://www.iea-shc.org/Data/Sites/1/publications/2021-07-Solar-Update-Newsletter.pdf • https://www.researchgate.net/publication/283713483_Building_Integrated_Solar_Thermal_BIST_Technologies_and_Their_Applications_A_Review_of_Structural_Design_and_Architectural_Integration • https://www.sciencedirect.com/science/article/pii/S0038092X17304607 Reference: • [1] http://solarheateurope.eu/project/batec-solar-heat-europe-facade-integrated-collectors-slagelse-denmark/ • [2] http://solarheateurope.eu/project/kingspan-environmental-thermomax-solar-heat-europe-hospital-rome/
EXAMPLES	Solar thermal panels can be applied at the building level like in Germany or at the district level, supplying district heating networks like in Silkeborg or Okotoks.

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Solar thermal panels	
	They can also be combined with heat pumps (Madrid case), like in PVT panels (hybrid photovoltaic-thermal panel).

3.1.11 Solar thermal systems with Evacuated Tube Collectors (ETC)

- Authors: **CARTIF**
- Knowledge Repository link: **https://netzerocities.app/resource-458**

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the “orange” fields of this solution, and then it has been afterwards reviewed by JRC and completed the “pink” fields, and the Knowledge Repository content has been updated with JRC’s input. So, here only the “orange” fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

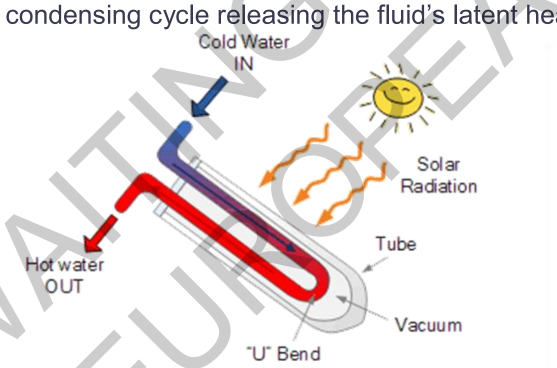
Solar thermal systems with Evacuated Tube Collectors (ETC)

Solar thermal panels are devices that convert solar radiation into heat and transfer it via fluid (typically, water or an anti-freeze fluid) to storage or the point of use. The most typical solar thermal modules are Flat-Plate Collectors (FPC) and **Evacuated Tube Collectors (ETC).**

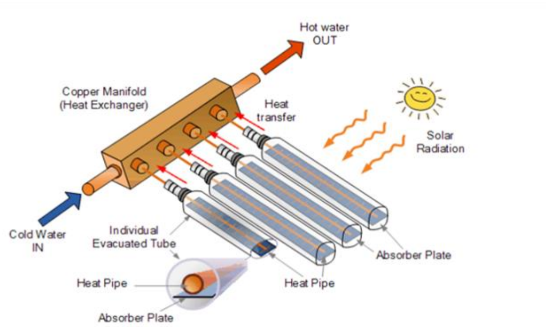
In the ETC the absorber plate and heat pipe are located in vacuum-sealed glass tubes to improve solar radiation absorption and reduce heat transfer losses, achieving a **greater performance ratio that allows heat production even in winter with low-light conditions and cold ambient temperatures.**

Both FPC and ETC are insulated to prevent heat loss, ETC has a greater performance ratio to its design with vacuum insulated glass tubes.

There are two types of ETC, the first one allows the transfer fluid to flow in and out of each tube; while the second feature a copper heat pipe inside the tubes as an efficient thermal conductor, which contains a small amount of non-toxic fluid as heat transfer medium that undergoes an evaporating–condensing cycle releasing the fluid’s latent heat.



Parts of the ETC without heat pipe[1]



Parts of the ETC with heat pipe and manifold

Solar thermal systems are usually implemented with a water storage tank, to reduce the production-demand fluctuations, have high operational safety, a great performance ratio, and can account for at least 25 to 30 years of lifetime. Both, FPC and ETC, are usually combined with auxiliary systems (e.g. biomass boiler, heat pumps, etc.) to supply the needs when no solar radiation is available. ETC can be used for domestic applications or coupled with DH a standard heat pump or boiler for heating and DHW supply (60-90ºC). For process heating in industries, ETC reaches higher temperatures (150ºC/180ºC) combined with high-temperature heat pumps. ETC combined with adsorption/absorption can be used for cooling supply.

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Solar thermal systems with Evacuated Tube Collectors (ETC)	
The decision between FPC and ETC could depend on price, temperature to be supplied, type of application, manufacturers, or environmental conditions. The main drawbacks are its mechanical fragility and mostly economic due to a greater initial investment cost.	
CO-BENEFITS	The ETC collectors allow the integration of more RES sources for domestic/residential needs, provides a "secure" heat source even in winter time, can be implemented with storage, or coupled with district heating increasing RES share and reducing fossil fuel consumption, and thus reducing the GHG/CO2 emissions. ETCs are a cost-effective way to improve RES integration in heating system with higher temperature ranges, with a long-life span and great performance and insulation that avoid heat losses.
KEYWORDS	Replaces the use of fossil fuels for heating purposes, as ETC can be combined with other RES sources like biomass, geothermal, and heat pumps powered with green electricity. Can be coupled with short thermal storage (such as water or a mixture of water-glycol tanks), Phase Change materials, geothermal (for storage) or seasonal storages, adsorption and absorption for cooling generation, and industry processes (if coupled with High-temperature heat pump).
EXTERNAL LINKS	• [1] https://www.alternative-energy-tutorials.com/solar-hot-water/evacuated-tube-collector.html • [2] https://www.iea-shc.org/Data/Sites/1/publications/Solar-Heat-Worldwide-2021.pdf • Applications to industry: • https://www.tvpsolar.com/attach/20170918_SHIP%20TVP%20Applied%20to%20Industrial%20Heat.pdf • To solar cooling: https://www.frimont.com/imagenes/tpv/TVP%20Applied%20to%20Solar%20Cool

3.1.12 Hybrid systems (PVT, PV +HP, …)

- Authors: **CARTIF**
- Knowledge Repository link: **https://netzerocities.app/resource-648**

Hybrid systems (PVT, PV +HP, …)
In the case of **PVT hybrid system, both heat and electricity is generated.** The heat production of these panels can be used to reduce fossil fuel consumption and at the same time, satisfy the same supply of domestic hot water and space heating. The **heat could also be supplied to a low-temperature district heating system to increase the RES contribution and avoid associated emission of GHG**. The main limitation is the temperature range (typically, 45ºC supply), thus **PVT is usually coupled with low-temperature demands, e.g. groundfloor heating or swimming pools, or with heat pumps to boost the temperature supply** (e.g. from 45ºC to 60ºC or 80ºC, depending on the heat pump). The electricity production can be used to power the building systems, be stored, or even be sold to the grid, increasing the RES contribution and generating money savings, and avoiding the emission of GHG. There are also some synergies in PVT panels like the optimization of the occupied roof area and better overall module efficiency, thanks to the reduction of hot spots and, the reduction of the module's temperature; increasing its life span and electricity production up to 5-15%. Some innovative examples are:

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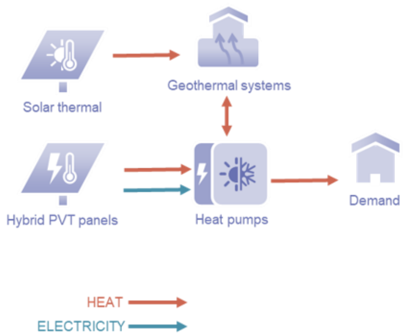
Hybrid systems (PVT, PV +HP, …)

- PV-T thermal output to be boosted with a reversible heat pump (that can use the panels even during the night) and electricity production to cover the heat pumps electricity consumption (where: in SunHorizon project, in northern countries with a CO2 heat pump and in southern countries with a reversible heat pump).
- Hybrid photovoltaic/thermal and ground source heat pump (PVT+GSHP), that can be implemented with energy storage/borehole recharge for direct heating and pre-heating.



PVT coupled with HPs and other systems [own ellaboration]

SUNHORIZON Madrid case [2]

Figure: PVT coupled with HPs and other systems, and PVT coupled with a reversible heat pump and a tank to produce space heating and domestic hot water needs. It could also be coupled with a swimming pool.

CO-BENEFITS	With a hybrid system there are **synergies that allow the production of heat and electricity in the same roof area, allowing a better urban integration,** and helping to **reduce the building's fuel consumption energy needs**, thus **preventing CO_2 emissions** related to the fuels or the electricity from the national grid. With these solutions, local energy production is being promoted, which can potentially enhance public engagement (through the energy communities constitution). Through innovation in this field the overall efficiency of the systems gets bigger, and it can transform into a more affordable and cost-effective solution, attractive for all citizens to implement
KEYWORDS	It can be directly connected to Heat pumps, geothermal, photovoltaics, etc. It can form a solution bundle with positive energy districts or energy communities.
EXTERNAL LINKS	• [1] https://ec.europa.eu/regional_policy/en/projects/Germany/solwp-hybrid-hybrid-solar-and-heat-pump-systems-for-energy-efficient-buildings-in-germany#:~:text=SolWP%2DHybrid%20is%20analysing%20hybrid,for%20energy%20generation%20and%20consumption • [2] https://sunhorizon-project.eu/emvs-gnf/ • https://www.sciencedirect.com/science/article/pii/S1364032121008479 • Tian You, Wei Wu, Hongxing Yang, Jiankun Liu, Xianting Li; Hybrid photovoltaic/thermal and ground source heat pump: Review and perspective; https://doi.org/10.1016/j.rser.2021.111569

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Hybrid systems (PVT, PV +HP, …)	
PRE-CONDITIONS & ENABLING CONDITIONS	***Climate and geography:*** As pre-condition ideally, the system needs solar radiation to be able economically feasible, but PV panels can work also with diffuse radiation (i.e. cloudy days). PVT instead will work much better in summer and climate conditions with high radiation all over the year (and mild temperatures). Ideally the system is located in a place

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Hybrid systems (PVT, PV +HP, …)	
	without shadows. If a PVT is coupled with HP, a tank is needed and sometimes is placed close to the PVT panels, which requires space a room. ***Urban form and layout:*** For very dense cities, PVT might be a greater option than only PV as there is double use of the same space, especially if coupled with HP in centralized systems (for supplying needs to multiapartment buildings). For not dense cities, space might not be an issue so a feasibility study should be performed. PVT+HP is also encouraged for efficient buildings with low temperature emitters (ground floor heating, fan coils). ***Technical infrastructure:*** Interoperability between systems (communication) is required, or at least the figure of “system integrator” (which can then develop an energy management system). **Social:** hybrid systems are not widely spread and is not so known by installers. Manpower education might be needed. ***Policy and regulatory/legal framework:*** A good relevant EU/national standards and regulations can help on wide spreading the solution, but there are not existing standards to hybrid/coupled systems which hinders its implementation. Nevertheless, local ordinances and guidelines can be created to boost its implementation. ***Funding and financing:*** Direct funds can help. But indirect funding can also be provided through local taxes reductions if citizens apply for the installation of such systems (like Sant Cugat with PV collective self-consumption taxes reductions). ***Project governance and implementation modalities:*** Models for engaging local private/public stakeholders (to know if they are aware of the technologies and its combination) and mobilisation of collective knowledge and skills (manpower) is needed.
CONSTRAINTS/ BARRIERS for implementation	***Urban form and layout:*** Space is an issue. It needs space in the technical room (for heat pump and storage), and roof or façades for solar installation. ***Technical:*** Pressure variations in PVT panels can cause heat pumps to stop functioning. Leakages of the refrigerants in heat pumps can cause issues (and can contaminate if there are not natural refrigerants) [1]. Both can be avoided by a good energy management system that includes proactive maintenance of the systems. To avoid freezing problems, refrigerant needs to be included in the solar loop too. The EMS should also consider the owners priorities (e.g. they want to maximize savings or they want to reduce GHG emissions), as well as country conditions (e.g. in Germany self-consumption is prioritised whereas in Latvia is more economically feasible to export energy rather than self-consume it for power-to-heat applications). ***Social:*** Hybrid systems are not widely spread and is not so known by installers which causes lack of skill man force, and increases the risk of installing such systems [2]. Stakeholder education might be needed. Low social acceptance may be linked to the perception of high investment costs, long payback periods, and lack of proper business models. Therefore, activities aimed at disseminating information about the technology in buildings should focus on tackling these issues as well as implement demonstrations that test innovative hybrid solutions. These projects should include the development and conduct of feasibility studies. ***Policy and regulatory/legal framework:***

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This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

Hybrid systems (PVT, PV +HP, …)	
	No existing standards to hybrid/coupled systems which hinders its implementation, as installers can see it as a risk. ***Funding and financing:*** The cost of the system can be higher (needs tanks between PVT and heat pumps, also storage after the heat pump, a good integration of the different systems, etc.). Financial concerns can influence adoption either positively or negatively. Economic incentives such as tax deductions or easy access to loans have been found to foster the adoption of technologies. However, investment costs and payback period are perceived hindrances to the adoption of technologies. ***Project governance and implementation modalities:*** There is no single provider that provides the hybrid solution as a package which requires coordination between different stakeholders and can cause problems if not planned properly. [1] https://sunhorizon-project.eu/d6-5-second-report-on-sunhorizon-monitoring-activities/ [2] Diego Peñaloza, Érika Mata, Nathalie Fransson, Håkan Fridén, Álvaro Samperio, Ana Quijano, Alessandra Cuneo. Social and market acceptance of photovoltaic panels and heat pumps in Europe: A literature review and survey. https://doi.org/10.1016/j.rser.2021.111867.
INSTRUMENTS/ Processes for implementation	• Local energy communities can implement this technology. https://netzerocities.app/resource-618 • Capacity building and training is required for manpower https://netzerocities.app/resource-1578 • Loans for Energy Efficiency (EE) could include this solution as a way for improving EE in buildings https://netzerocities.app/resource-1648 . Same applies to Blended finance for Energy Efficiency (EE) https://netzerocities.app/resource-1658 • Building Renovation Passport (BRP) could include this solution as example. https://netzerocities.app/resource-1748 • One-stop-shop for building renovation https://netzerocities.app/resource-1913 • User Engagement for Energy Performance Improvement https://netzerocities.app/resource-1498
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	In Verviers the solution was proposed for two public buildings. Tenders were published with an estimation of how the system should be, but installers did not know the technologies and did not know how to integrate them as single unit. Thus, they considered the project as a risk and asked for very high amounts of money to deploy the action. Finally, the action was cancelled as the installers could not assume the risk neither the municipality assume the higher costs. If the benefits of the solution would have been presented to stakeholders (showing the good opportunities like treating the site with an ESCO model or a “heating as a service” business model, or using the heat pumps for participating in demand response markets) the project could have been deployed. In many sites of SUNHORIZON project the lack of communication among technology providers have delayed the progress of the implementation and many losses of resources (very time consuming). (D6.5 in https://sunhorizon-project.eu/) In Madrid, there is a local ordinance that hinders the efficiency of the panels as they force to increase the parapet (safe wall in the roof) which causes shadows in the panels. This also happens in Valencia, and other municipalities of Spain. Furthermore, many countries do not allow to use the excess of production to inject it to the grid (Hungary, etc.). Thus, the economic feasibility of the solution is hindered: you cannot export and reimburse part of the energy consumed from grid, which causes the economic case to be worse as you need to self-consume it.
	It is possible to enhance the performance of PVT panels, when coupled with brine-water heat pumps.

AWAITING VALIDATION BY THE EUROPEAN COMMISSION

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Hybrid systems (PVT, PV +HP, …)

IMPACTS (Indicators & DNSH)

33-70% GHG emissions savings and 30-85% operation costs savings can be achieved, when we compare the performance of Hybrid options with a gas boiler system and an air conditioner

Demo location/TP	Sizing	Baseline PE [MWh] / OPEX [k€]	PE reduction [%]	GHG emissions reduction [%]	OPEX reduction [%]
Berlin/TP1	Solar field: 14m², TES: 1.5 m³ HP: 20kW	40.5 / 2.3	36	36	30
Riga/TP2	Solar field: 50m², TES: 1.3 m³ HP: 20kW	27.9 / 1.6	42	51	39
Saint Cugat/TP3	Solar field: 220m², TES: 10 m³, HP: 20 kW (sorption) + 40 kW (compression)	155.3 / 18.6	33.4	33.4	33.4
Madrid/TP4	Solar field: 71m², TES: 1m3 SH/SC - 1.3m3 DHW, HP: BWHP 9kW - AWHP 27kW	78.3 [1] (gas for DHW and SH+ air conditioning for cooling) / 10.8	76.1	70.3	84.8

SUNHORIZON project impacts. Source: http://proceedings.ises.org/paper/eurosun2020/eurosun2020-0042-Cheze.pdf

TP1: gas-driven heat pump in parallel to solar thermal panels; TP2 gas-driven heat pump integrated with PVT panels; TP3 solar thermal panels integrated with a hybrid adsorption-compression heat pump; TP4 PVT panels with brine water heat pumps and in parallel to an air-water heat pump as back-up.

[1] Considering only AWHP supply for heating and cooling, the simulation estimates 41.3 MWh PEnren consumption, SCOP=2.7 and SEER=4.3. With PVT integration with BWHP reaches higher energy savings and increased SCOP=3.59 compared to AWHP alone since it runs as support in heating mode.

DNSH:

Climate change mitigation

This activity that leads to significant greenhouse gas emissions on a lifecycle basis

Circular economy

If second life materials are used for heat pumps or PV panels, then it can increase circularity. Thus, it does not harm this activity.

Pollution prevention and control

This activity leads to a reduction of pollutants when it is applied to an existing building and removes a pollutant system.

Additional information from CASE STUDIES

In residential and public buildings: https://sunhorizon-project.eu/

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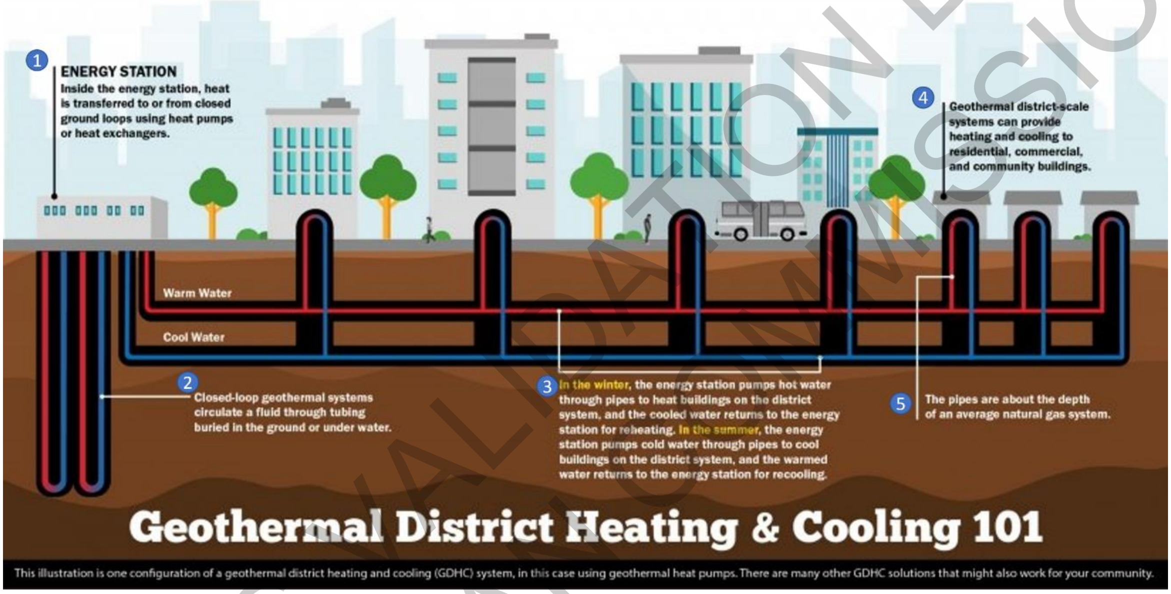
3.1.13 Geothermal energy for H&C

- Authors: **REGEA**
- Knowledge Repository link: https://netzerocities.app/resource-668

<table>
<tr><th colspan="2">Geothermal energy for H&C</th></tr>
<tr><td colspan="2">

Geothermal energy has a long tradition in human history, from thermal baths to heating and power generation. It represents an important resource of **renewable energy**.

Geothermal heating plants can come in a variety of types depending on the geological conditions, availability of geothermal water and the needed supply temperatures in the heating system. Depending on the configurations and available resources, **geothermal water** can be used directly if at sufficiently high temperatures, using heat exchangers. Alternatively, **heat pumps** can be utilized to raise the temperatures to the needed levels. If geothermal water is not available, other mechanisms can be used to exploit available energy from underground with or without heat pumps.



Source: Geothermal Technologies Office - Community Geothermal Heating and Cooling Design and Deployment. 1) Inside the energy station, heat is transferred to or from closed ground loops using heat pumps or heat exchangers. 2) Closed loop geothermal systems circulate fluid through tubing buried in the ground or underwater (or water from a river). 3) In the winter, the energy station pumps hot water through pipes to heat buildings in the district system, and the cooled water returns to the energy station for reheating; In the summer the energy station pumps cold water through pipes to cool buildings on the district system, and the warmed water returns to the energy station for freecooling. 4) Geothermal district-scale systems can provide heating and cooling to residential, commercial, and community buildings. 5) The pipes are about the depth of an average natural gas system.

The **drilling works** represent the majority of the costs of these systems so the depth at which energy sources are available will have a significant impact on the viability of the exploitation of geothermal energy.

Geothermal energy has a strong potential to be used in a cascading way from **power generation** at high temperatures to **heating**, **healthcare**, **pools** and **greenhouses** as the temperatures are reduced. In case **higher temperatures** are available, it is recommended to use geothermal energy for **both power and heat production**. For heating purposes, temperatures that are up to 100°C are used, either directly or with help of a heat pump.

</td></tr>
<tr><td>CO-BENEFITS</td><td>The use of Geothermal energy for heat production can greatly Reduce GHG emissions and Increase technological readiness locally and regionally.</td></tr>
<tr><td>KEYWORDS</td><td>Direct links with renewable heating and cooling, energy efficiency of distribution networks, heat storage.</td></tr>
</table>

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Geothermal energy for H&C	
EXAMPLES	• Geothermal district heating in Bilbao or Szeged (Hungary) • Shallow geothermal energy for heating and cooling in Madrid • More projects in https://www.geoenergyeurope.com/case-studies • Smart geothermal heat grid in Heerlen, The Netherlands • District heating geothermal plant in Montieri (Italy): https://www.youtube.com/watch?v=GBc9V9PegY0

Geothermal energy for H&C	

PRE-CONDITIONS & ENABLING CONDITIONS	Geothermal resources vary widely from one location to another, depending on the temperature and depth of the resource, the rock chemistry and the abundance of groundwater.
	
	Ground temperature and hydrogeological conditions are **key parameters** for many engineering applications, such as the design of building basements and underground spaces and the assessment of shallow geothermal energy potential. The **scalability and profitability** of geothermal projects is now being reassessed with the advance of hydrocarbon industry technology. Horizontal drilling or HPHT (High Pressure and High Temperature technology) is one such example, as it can be used to drill deeper, and access hotter geothermal fluids. This would make previously ignored locations, geothermally accessible and worthy of investment. Also, our geological understanding in several areas has increased, ironically brought on by the shale boom, a facet of the hydrocarbon industry that has been historically controversial. It may still hold some of the answers to support de-risking geothermal project investment.
	
	Reusing existing infrastructure can further decrease both risks and costs. By repurposing existing heat, such as re-using disused mine waters (already produced to mitigate against potential water resource pollution) can be an effective way to heat spaces. A great example of this is the Seaham Garden Village in County Durham, UK. The other return on investment is, of course, the benefits in supply. To put some numbers in perspective, typical coal power plants have average availability of 75% (i.e. producing energy more than 75% of the time) or thereabouts. In comparison, geothermal plants are closer to 90% and are available 24 hours a day, 365 days a year!
	
	Policy and regulatory/legal framework:
	Exploitation of our natural resources is generally heavily regulated, and rightly so. To protect people and environment these regulations must be strictly enforced. Many regulations and permits differ from country to country, and in many cases, between regions in a single country. This can make the process complex leading to confusion, slowing down project delivery and in some cases cancelling a project all together. Some of the existing loans and subsidies in EU countries are:
	• Tax benefits in Hungary and France;
	• Loans in Germany, Lithuania (theoretically) and Slovenia;
	• Direct subsidies in Belgium, Germany (limited), Lithuania and Slovenia;
	• Various forms of indirect support in most countries;
	• Guaranteed incentive prices (still only for electricity):
	    ○ Germany: 8-15 €-ct/kWh
	    ○ Hungary: 12-14 €-ct/kWh
	    ○ Slovenia: 5.86 €-ct/kWh
	    ○ Austria: 7 €-ct/kWh
	• Green certificates in Hungary and Romania;
	• Carbon credits in Romania (first positive experiences in geothermal energy with Denmark as a partner, 5 €/t of reduced CO2), Germany, Poland (they exist, but do not yet have an impact on geothermal energy);
	• Geothermal risk coverage, which is crucial for private investors.,

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<table>
<tr><th colspan="2">Geothermal energy for H&C</th></tr>
<tr><td></td><td>From the support measures mentioned above, 3 successful measures stand out, namely:
• Loans/subsidies for installation;
• Incentive prices (in accordance with relevant regulations);
• Carbon credits.

Funding and financing:
Subsidies from governments, incentives that include risk insurance, shared costs of drilling between public and private sectors are just some of the other ways to mitigate initial capital risk.
Horizon Europe, NER 300 programme, European Climate Infrastructure and Environment Executive Agency (CINEA), European structural and investment funds (ESIF), LIFE, Prize for renewable energy islands</td></tr>
<tr><td>CONSTRAINTS/ BARRIERS for implementation</td><td>Early risks will naturally be closely followed by early costs. For example, the US Department of Energy (UoE) estimates that the initial cost for the field and power plant could be around $2500 per kW installed. While that is not something to scoff at, it's important to remember that the return on that investment could be much faster than you might expect. Carbon taxes would be the first and most obvious example associated with a new geothermal energy plant. Exploration costs could also be reduced by increasing the publicly available geological data, (although this often requires mandatory regulatory compliance). Access to old mine records or previously drilled wells would help to further reduce assessment costs, streamline the permitting process and regulatory compliance. With robust cost modelling, a geothermal project can be planned in such a way as to reduce upfront spend, mitigate and, in some cases minimise the risk of well exploration. Subsidies from governments, incentives that include risk insurance, shared costs of drilling between public and private sectors are just some of the other ways to mitigate initial capital risk.

One of the main challenges that geothermal energy faces, is the ignorance of the general public. In the case of geothermal power generation, the absence of a favourable regulatory framework results in the complete lack of power plants.
In many cases, the high initial costs of applying geothermal energy represents a barrier, even though the system's total cost for the entire period of use is very satisfactory.

Promoting and marketing geothermal heat pumps can be presented as pedagogical or educational challenges. Marketing arguments that should be highlighted and appreciated when promoting a geothermal heat pump are environmental protection and comfort of use.
Energy prices, which only partially reflect the external costs of different energies, are a significant obstacle in some European countries. Even if heat pumps are economically competitive, the difference in energy costs may be too small to decide on heat pumps despite other benefits that the heat pump system offers (such as reducing CO_2 emissions, more comfort, etc.) This barrier can only be overcome by offering subsidies, tax breaks for renewable energy that uses heat pumps, exemption or reduction of taxes for CO_2 reduction, etc.</td></tr>
<tr><td>INSTRUMENTS/ Processes for implementation</td><td>Some studies show the importance of land management (planning, agriculture, conservation) and geographic studies to implement energy strategies. Geothermal energy can be put into a myriad of uses and many have already been studied, though most of them are still in pilot stage—from electricity production to urban heating or agricultural applications, such as greenhouse and stockbreeding facilities heating, besides industrial applications through the use of underground infrastructures, heating for residential and official buildings and swimming pools, just to name a few.
• Local energy communities: https://netzerocities.app/resource-618
• Loans for Energy Efficiency (EE): https://netzerocities.app/resource-1648</td></tr>
</table>

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Geothermal energy for H&C	
	• Blended finance for Energy Efficiency (EE): https://netzerocities.app/resource-1658 • Integrated land use and urban planning with energy and climate: https://netzerocities.app/resource-1678
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	A growing number of studies point at the drawbacks of geothermal energy, including runaway emissions, water pollution, seismic activity, and potentially low net energy returns [1], [2], [3], [4], [5]. It is timely to note that the geothermal sector, IRENA, the World Bank, and the European Bank for Reconstruction and Development (EBRD) differ in how they portray the promises and pitfalls of geothermal energy as a decarbonization strategy. [1] M. Soltani, et al; Environmental, economic, and social impacts of geothermal energy systems Renew. Sust. Energ. Rev., 140 (2021), Article 110750 [CrossRef] [2] R. Shortall, et al ; Geothermal energy for sustainable development: a review of sustainability impacts and assessment frameworks, Renew. Sust. Energ. Rev., 44 (2015), pp. 391-406, [CrossRef] [3] T. Kunkel, M. Ghomshei, R. Ellis, Geothermal energy as an indigenous alternative energy source in British Columbia, Br. Columbia J. Ecosyst. Manage., 13 (2012), pp. 1-16 [4] ThinkGeoEnergy, Geothermal (2021) https://www.thinkgeoenergy.com/geothermal/ [5] M. del Castillo-Mussot, et al ; Impact of global energy resources based on energy return on their investment (eroi) parameters, Perspect. Glob. Dev. Technol., 15 (2016), pp. 290-299
IMPACTS (DNSH)	***DNSH:*** ***Climate change mitigation*** This activity leads to a significant greenhouse gas emission reduction on a lifecycle basis ***Climate change adaptation*** By 2050, deployment of carbon-free geothermal energy can help address the climate change crisis by offsetting more than 500 million metric tons (MMT) of greenhouse gases in the electric sector and more than 1,250 MMT in the heating and cooling sectors. ***Circular economy*** In the power sector, geothermal deployment can grow to provide 60+ gigawatts-electric (GWe) of firm, flexible clean energy by 2050, with a major expansion of geothermal power production ***Pollution prevention and control*** Geothermal power plants emit 97% less acid rain-causing sulphur compounds and about 99% less carbon dioxide than fossil fuel power plants of similar size. **Geothermal power plants use scrubbers to remove the hydrogen sulphide naturally found in geothermal reservoirs.** This activity leads to a reduction of electricity consumption, and consequently to a reduction of emissions.
Additional information from CASE STUDIES	• Geothermal power plant case studies: read here • GEOTeCH project has made innovations in drilling and extraction technology that could help further release the power of these underground energy resources for buildings: https://www.geotech-project.eu/ • Sanyé-Mengual, E.; Romanos, H.; Molina, C.; Oliver, M.A.; Ruiz, N.; Pérez, M. Environmental and self-sufficiency assessment of the energy metabolism of tourist hubs on Mediterranean Islands: The case of Menorca (Spain). Energy Policy 2014, 65, 377–387. [CrossRef] • Sibbitt, B.; McClenahan, D.; Djebbar, R.; Thornton, J.; Wong, B.; Carriere, J. The performance of a high solar fraction seasonal storage district heating system—Five years of operation. Energy Procedia 2012, 30, 856–865. [CrossRef] • U.S. Department of Energy. Energy 101: Geothermal Energy. Source: https://www.youtube.com/watch?v=mCRDf7QxjDk

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3.1.14 Sustainable biomass and biogas technologies

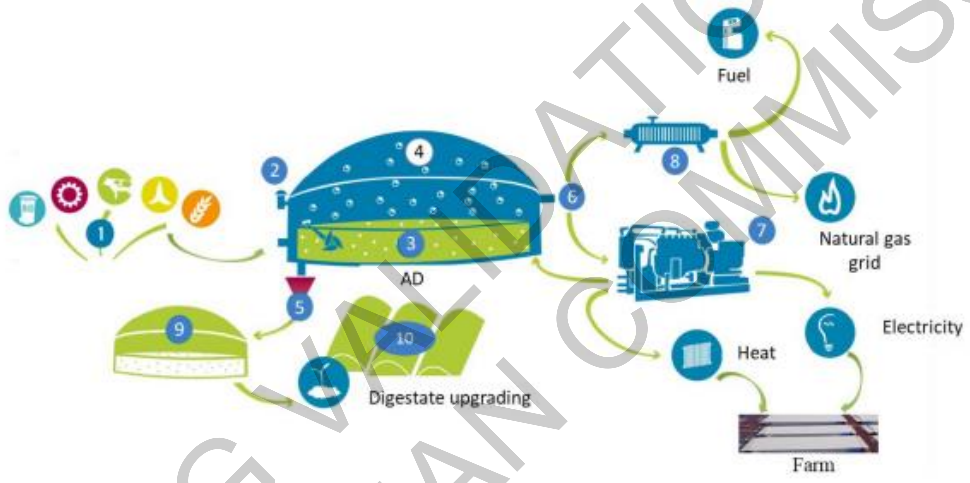
- Authors: **REGEA**
- Knowledge Repository link: https://netzerocities.app/resource-678

Sustainable biomass and biogas technologies

Biomass is defined as organic matter derived from plants or animals available on a renewable basis. Cities **can collect waste biomass to produce biogas, or can get the wood biomass from the region.**

As it is distributed worldwide, one of the advantages of biomass utilization for energy is that almost every country can utilize its own resources. Moreover, since it is easy to store, it can be used for peak load generations of electrical energy.

Nevertheless, to ensure a secure supply, long-term contracts with the supplier need to be made. **The suggested use for biomass in the city is a modern combined heat and power generation (CHP) connected to a district heating network or biofuels production.** Although different sizes of biomass boilers that fit any need can be found on the market, domestic use of biomass should be avoided in the cities due to the emissions of fine particles that pollute the air.



Explanation: (1) Different feedstocks, (2) safety equipment, (3) anaerobic digester, (4) gas storage, (5) sanitation, (6) gas cleaning system for desulfurization, (7) combined heat and power unit (CHP), (8) gas treatment system for biogas upgrading (fuel and CNG), (9) Digestate storage, and (10) digestate upgrading (optional). Source: Practical biogas plant development handbook, https://open.unido.org/api/documents/25481236/download/Biogas%20handbook_English%20version.pdf

There are further high-efficiency biomass uses that have been rapidly increasing worldwide, such as fluidized bed combustion, co-firing with fossil fuels, CHP co-generation and gasification. A range of biomass pre-treatment and upgrading technologies, such as palletization, torrefaction, and pyrolysis, have been developed in order to improve biomass characteristics and to make handling, transportation and conversion processes more efficient and cost-effective. Anaerobic digestion for biogas production from wet biomass is a small-scale biomass CHP application. Biogas may also be upgraded to mix with natural gas and be used in natural gas grids or to power vehicles as compressed natural gas (CNG).

CO-BENEFITS	The use of biomass and biogas increases access to clean, affordable, and secure energy, boosts local business and increases employment rate and jobs. Since waste materials can be converted to energy, the utilisation of biomass and biogas in energy production can achieve better waste management and reduce food waste.
KEYWORDS	Biomass is linked with on-site and nearby renewable energy generation (heat/cold), on-site and nearby renewable energy generation (electricity), sustainable Biofuel

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Sustainable biomass and biogas technologies	
	from biomass fermentation process, Sustainable Biofuel (biomethanol, drop-in fuel, jet fuels, biodiesel) from biomass thermochemical process (gasification, pyrolysis, Fisher Tropsh, Hydrotreatment, Esterification) It can form a bundle with energy-efficient co-generation systems (CHP, CHCP = combined heat, cooling and power, mCHCP = micro-CHCP,…)
EXTERNAL LINKS	• https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/IRENA-ETSAP_Tech_Brief_E05_Biomass-for-Heat-and-Power.pdf • https://www.researchgate.net/publication/347459848_Biomass_Conv
EXAMPLES	• Lund biomass-based DHN: http://www.cityfied.eu/news/press-releases/cityfied-technical-visit-district-heating-production-in-lund.kl

Sustainable biomass and biogas technologies
Go to **Sustainable biomass and biogas power** (**3.2.5**) https://netzerocities.app/resource-808, within the Thematic Area of **Energy Generation**, to see the "pink" fields, as they are the same applicable to this similar solution.

3.1.15 Building Automation and Control Systems (BACS)

- Authors: **AIT**
- Knowledge Repository link: **https://netzerocities.app/resource-758**

Building Automation and Control Systems (BACS)
Building automation and control systems contribute to the energy-efficient operation of buildings of all use types. They enable the energy-efficient and cost-effective integration of local renewable energy supply technologies, as well as the management of energy storage and flexibilities to optimally balance energy demand and supply in the operation of building energy systems. The market for building automation systems provides several tested approaches and commercial solutions e.g. BEOS from Siemens, which is showcased in Seestadt Aspern Vienna. Additionally, aspects of building maintenance can be integrated in building automation systems, which allows for maintenance demand predictions that enable the cost-effective operation of buildings.

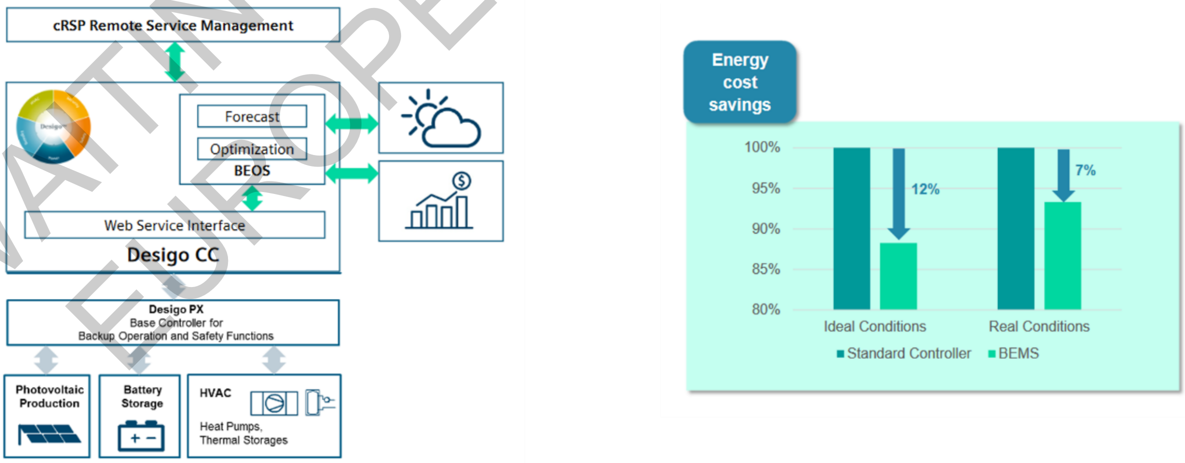

Figure: Overview of Building Automation and Control system applied in Vienna- Copyright Siemens (https://assets.new.siemens.com/siemens/assets/api/uuid:d9035c01-2e7c-47b3-973a-c523d49cb626/bems-building-energy-management-system-siemens.pdf)

There are a few solutions for implementing smart energy efficiency solutions for already efficient office buildings, developing tools to communicate about office building's energy efficiency solutions to users,

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Building Automation and Control Systems (BACS)	
and motivating them to complement individual energy efficiency measures. Smart energy efficiency solutions included implementing and testing several features that utilise new smart thermostats, an upgrade to the building automation system, and the development of communicative tools for building energy-saving features.	
CO-BENEFITS	Using building automation and control system can prepare an Enhance stability of the urban infrastructure and Increase access to clean, affordable, and secure energy.
EXTERNAL LINKS	• https://assets.new.siemens.com/siemens/assets/api/uuid:d9035c01-2e7c-47b3-973a-c523d49cb626/bems-building-energy-management-system-siemens.pdf • https://www.youtube.com/watch?v=J4nFkB_TWcg&t=1428s • https://www.mysmartlife.eu/fileadmin/user_upload/Info_packs/info-packs_pdf/Smart_office_building_demonstrations___fin.pdf

Building Automation and Control Systems (BACS)	
PRE-CONDITIONS & ENABLING CONDITIONS	***Political:*** Raising awareness of the technology's benefits, requirements and potential role in urban decarbonization. The use of the technology could be incentivised by tax benefits, or subsidies. Building regulations can integrate requirements for the use of building automation and controls systems, or at least the installation of enabling equipment, e.g., smart meters, smart control units, and communication infrastructure. ***Economic:*** Building automation and control systems allow more energy efficient building operation, leading to reduced energy cost. High energy prices further incentivise energy efficient behaviour and therefore the use of the technology. Furthermore, building automation and control systems, in combination with storage capacities, can shift energy consumption. Time flexible energy tariffs therefore further incentivise the use of the technology. ***Social:*** Awareness of energy efficiency potentials and their importance. ***Technical:*** Buildings with a high thermal standard benefit more from building automation and control systems, as they often feature low temperature heating systems and mechanical ventilation systems that can be centrally operated and influenced. Beside heating and ventilation systems that can utilize the technology, a variety of sensors for physical parameters in the building, e.g., temperature, humidity, occupancy, is required. ***Legal:*** Implementation and promotion in building regulation
CONSTRAINTS/ BARRIERS for implementation	Main barriers/obstacles that should be considered and what are the most typical barriers found that can hinder the implementation of the solution. Also considering connections with other areas. ***Political:*** Lack of awareness for importance of technology ***Economic:*** Lack of economic incentives, e.g., energy price, flexible energy tariffs, ***Social:*** Missing know how and workers in construction industry, distrust towards the technology ***Technical:*** Lack of sensors and digitalized meters, e.g., unfinished roll-out of smart meters, incompatible heating and ventilation system. ***Legal:*** Data privacy

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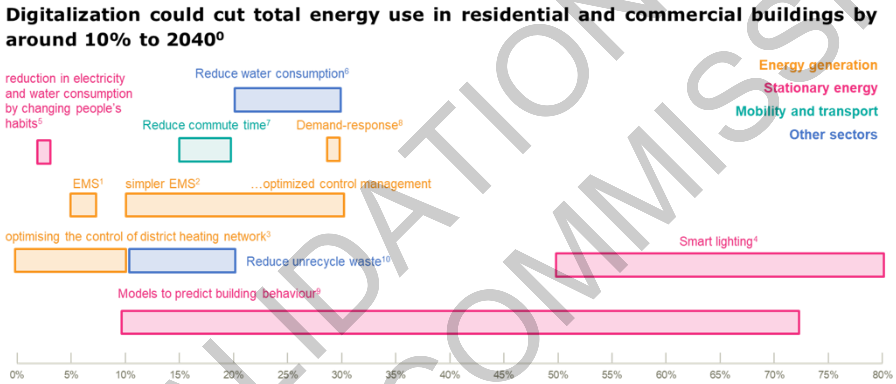
<table>
<tr><th colspan="2">Building Automation and Control Systems (BACS)</th></tr>
<tr><td>INSTRUMENTS/ Processes for implementation</td><td>Instruments for a wide implementation building automation and control systems could be adapted building regulations that integrate the technology.
Also, establishing and following data standards on building energy data via regulations could be a useful instrument. Furthermore, aspects of building. Automation and control systems could be further integrated in the education of practitioners to ensure the availability of know how.</td></tr>
<tr><td>DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation</td><td>Drawbacks can consist of faulty building operations if automation systems are installed wrongly. Additionally, the introduction of digital sensors and meters can be related to privacy issues, as sensitive data is processed.</td></tr>
<tr><td>IMPACTS (Indicators & DNSH)</td><td>What do you achieve (Specific energy saved (compared to conventional technology): MWh/MW, Specific costs saved, Specific emissions saved)? How much it costs (Capex, OPEX), also considering connections with other areas. how to consider carbon sink/storage (mitigation solution), add formulas for calculating in an easy way, ask context to cities and make a calculation of indicators for that specific context.


Digitalisation impact, source : https://op.europa.eu/en/publication-detail/-/publication/864bbbe7-f1d9-11ec-a534-01aa75ed71a1/language-en
<table>
<tr><th></th><th>UK</th><th>Germany</th><th>Spain</th><th>France</th><th>USA</th><th>unit</th></tr>
<tr><td>Building energy management systems (electricity commercial)</td><td>528.63</td><td>312.39</td><td>554.19</td><td>54.98</td><td>837.23</td><td>kgCO₂e/smart</td></tr>
<tr><td>Building energy management systems (gas commercial)</td><td>3,967.95</td><td>2,593.98</td><td>579.12</td><td>1,961.62</td><td>2,320.50</td><td>kgCO₂e/smart</td></tr>
<tr><td>HVAC control commercial buildings</td><td>9,042.50</td><td>5,527.13</td><td>7,257.54</td><td>5,577.09</td><td>11,993.49</td><td>kgCO₂e/avera</td></tr>
<tr><td>HVAC control residential</td><td>398.87</td><td>271.07</td><td>168.6</td><td>133.71</td><td>716.25</td><td>kgCO₂e</td></tr>
<tr><td>Smart meters water</td><td>15.24</td><td>15.24</td><td>15.24</td><td>15.24</td><td>20.79</td><td>kgCO₂e/smart</td></tr>
<tr><td>Smart meters water</td><td>1.21</td><td>0.83</td><td>1.2</td><td>1.22</td><td>3.57</td><td>kgCO₂e/smart</td></tr>
<tr><td>Smart meters (electricity</td><td>64</td><td>56.02</td><td>45.13</td><td>12.34</td><td>197.03</td><td>kgCO₂e/smart</td></tr>
<tr><td>Smart meters (gas</td><td>56.56</td><td>29.49</td><td>11</td><td>25.47</td><td>42.92</td><td>kgCO₂e/smart</td></tr>
</table>
National digitalisation impact, source: https://prod-drupal-files.storage.googleapis.com/documents/resource/public/Mobile%20Carbon%20Impact%20-%20REPORT.pdf</td></tr>
<tr><td>Additional information from CASE STUDIES</td><td>The aforementioned building automation and control system provided by Siemens (BEMS) was successfully demonstrated in Aspern Seestadt in Vienna, Austria.
In Use Case 12, where energy demand and flexibility usage are optimized in a student dorm and office buildings (https://www.ascr.at/wp-content/uploads/2022/03/2022-UC12-DE.pdf)</td></tr>
</table>

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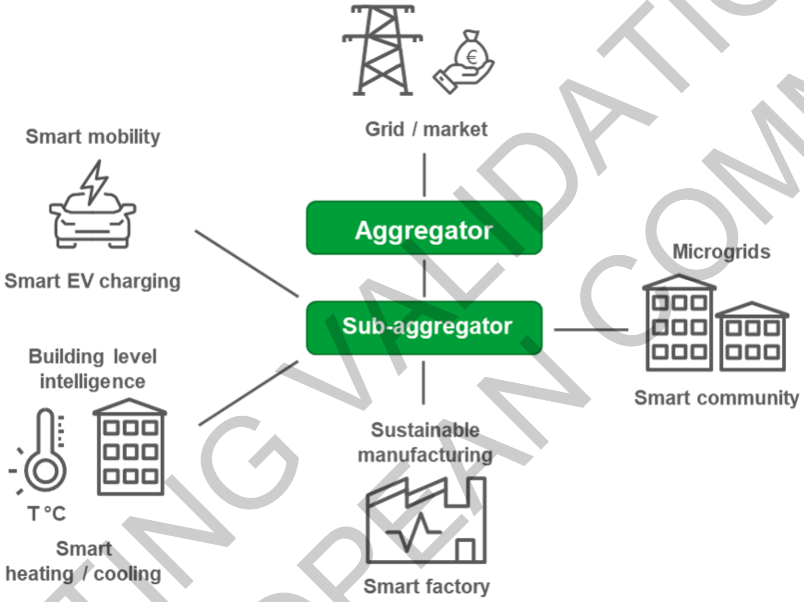
3.1.16 Demand management

- Authors: **VTT**
- Knowledge Repository link: **https://netzerocities.app/resource-91**

This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

Demand management	
The development of sustainable and climate neutral energy production will increase a lot of new fluctuating renewable energy generation to the grid. This increases the need for new methods to balance the electricity grid. **Demand response is a method for matching the demand for energy to the available supply of energy** (ISO/IEC 15067-3:2012). Demand response is typically classified as implicit and explicit demand response. Implicit demand response services include among others time-varying electricity prices, critical peak pricing, real-time pricing, or time-varying electricity tariffs. In explicit demand response, the result of demand response actions is sold upfront on the electricity markets through the services of single large consumers or by aggregators via an aggregated pool of controllable loads (e.g. electrical loads in buildings or charging of electric vehicles). With demand response services it is possible to shift electric load to another time, reduce grid-related electric load, increase the grid reliability in a case where the maximum capacity is reached, and reduce the need to build new capacity or reduce to use of old fossil energy based electric power plants for peak electric generation. **Balancing the power grid** with a virtual power plant that consists of thousands of aggregated buildings can boost the utilization of intermittent renewable energy sources, and the demand side can be better adapted to available RES generation with the load shifting. Production for peak consumption is often done with high-emission-based energy production. Consumption-related flexibilities provide an inexpensive solution to increase flexibility in the system instead of building more power generation to control the capacity. Flexibility must be implemented in such a way that residents do not notice it e.g. poor indoor conditions.  *Figure: Demand response operators (source: VTT Technical Research Centre of Finland Ltd. 2022).*	
CO-BENEFITS	Demand response can increase **access to clean, affordable, and secure energy**. Demand response can ease the challenges of carbon neutral transition of the energy system. The electrification of society increases the demand for electricity, e.g. data centers, electric vehicles, heat pumps, etc. At the same time, renewable energy is becoming cheaper: the price of solar and wind power has fallen rapidly and is already cheaper in some places than electricity produced with fossil fuels. **Weather-dependent RES production increases the need to balance the electricity grid**. In addition, battery technologies have developed rapidly. Demand response can also **reduce the energy costs for peak power timing**. There are high price peaks in the electricity market and reserving capacity for those binds capital and affects consumer prices. The capability for cutting peak power can reduce the size, and thereby the price of the electricity connection to the power grid if the peak power capacity needed would be smaller.

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Demand management	
KEYWORDS	Demand response is linked with: Building automation and control systems (BACS); home energy management system (HEMS); AI-based energy management agents... It can form a solution bundle (or a package of solutions) with monitoring and control systems (e.g. smart meters, intelligent devices, aggregators' energy management systems), local RES, energy storage, EV charging, and standard-based ICT solutions (system interoperability). The bundle can be used for Nearly Zero Energy Building (NZEB), Positive energy building (PEB), Positive energy district (PED) or Virtual power plant (VPP). Connections also with: • Economic incentive to connect buildings • peak power cutting: reducing energy costs.
EXAMPLES	• iFLEX EC funded project about demand management, link to deliverables • MySmartLife SCC Lighthouse project: demand management demonstrations in the lighthouse city of Helsinki

Demand management	
PRE-CONDITIONS & ENABLING CONDITIONS	***Technical aspects:*** Solution requires both technical interoperability and the contract for demand management with an aggregator. Data transfer standards and technical interoperability are required for the whole demand management chain (from aggregator to building level). ***Economic context:*** Business models for sharing the economic benefits of the demand management for all participants (win-win-model). Business models for profitable integration of local intermittent RES production to the grid.
CONSTRAINTS/ BARRIERS for implementation	***Policy and regulatory/legal framework:*** Related to removing legal and regulatory barriers for energy communities: Among others, the current legalisation hinders the selling of electricity to neighbouring plots; and the taxation of the capacity limits small-scale power generation. Lots of variation in national level regulatory barriers, depending on the level of development in the country. ***Economic:*** The economic incentive for the building owner is still often quite minor: the economic benefit of the demand management can be small for a single building, even when virtual power plants formed from large building masses would be very beneficial for the overall sustainable power generation. ***Technical:*** Technical readiness (both hardware and software) is currently often missing from the buildings; usually small investments are required at the buildings to start using demand management in a building. Intelligent algorithms (AI-based energy management agent) are usually missing.
INSTRUMENTS/ Processes for implementation	Demand management is often one element in energy communities (https://netzerocities.app/resource-618)
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	***Building owners have difficulties seeing and getting the economic benefit:*** it is very small for the building owner, which is a drawback for the broader uptake of demand response. (For example, case studies with 1000€ profit per year for an individual building owner, against the cost of adjusting building systems: the profit is rather small and has not been very motivating, at least before 2022). Extra

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<table>
<tr><th colspan="2">Demand management</th></tr>
<tr><td></td><td>benefits could come also via additional services, e.g. related to the building performance and status.

Systems are not standardized now: every case needs to be built from scratch. Interoperability and standards would solve this, and ease the starting to implement the demand response.</td></tr>
<tr><td>IMPACTS (Indicators & DNSH)</td><td>Impacts should be monitored on the aggregators' side or on the power grid side:
Energy savings are assessed via energy flows and energy balance: this requires an optimized overall energy system, including demand, generation, storage, and energy sold/bought (MWh: total, per m²).
District heating networks: Peak shaving up to 30%, reduction of primary energy needs up to 5%.https://doi.org/10.1016/j.energy.2020.119440
Application in 27 buildings of student apartment in Finland(Tampere): peak reduced up to 15% and energy/cost/emissions reduced up to 9% https://www.mdpi.com/2624-6511/3/2/9
Building level indicators
Aggregator level indicators
CO2 reduction impact: from the total electricity generation status to the grid at each time (which energy sources are being used, transferring loads to times that have more sustainable energy production): (this can be difficult in practice)
Costs of energy (at each time): (this can be difficult in practice)
Demand response management strategies at district level have been estimated in Groningen as having the potential to reduce energy costs by 30% (MAKING-CITY project)</td></tr>
</table>

3.1.17 Freecooling opportunities (Air-to-air heat exchangers)

- Authors: **CARTIF**
- Knowledge Repository link: https://netzerocities.app/resource-728

Freecooling opportunities (Air-to-air heat exchangers)
The **free-cooling systems are based on a simple idea**: exchange indoor air with outdoor air, which allows you for **conditioning a zone for free**. Free cooling cannot be used alone as it depends a lot on climate conditions, so it is usually applied together with a mechanical ventilation system or air-conditioning system In air-to-air heat exchangers, there are three modes of function: heating, cooling, and free cooling. In the heating and cooling mode the system uses the outside air temperature conditions for the indoor spaces, the system reduces the heating and cooling demand by using a heat exchanger to pre-heat or pre-cool the new inlet air from the outside. The heating and cooling are usually done with a compressor system (like a heat pump). The air system can also promote air quality with filters (e.g. corrugated cardboard filter which has an effective sound attenuation) and improve also the humidity levels with humidifiers and dehumidifiers. Free cooling is an energy-efficient solution characterized by an efficient control system that allows you to pump air from the outside to the inside when conditions are good. This way the compressor of the heat exchanger is not used. This mode is very **useful when the outdoor air temperature is lower than the temperature from the inside** (For example during summer nights), which allows you to cool down your building for free. In humidity areas instead of temperature control, an enthalpic control is needed to do free-cooling without adding too much humidity to your zone. Thus, it can only be used, whenever the climatic conditions are favourable.

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Freecooling opportunities (Air-to-air heat exchangers)

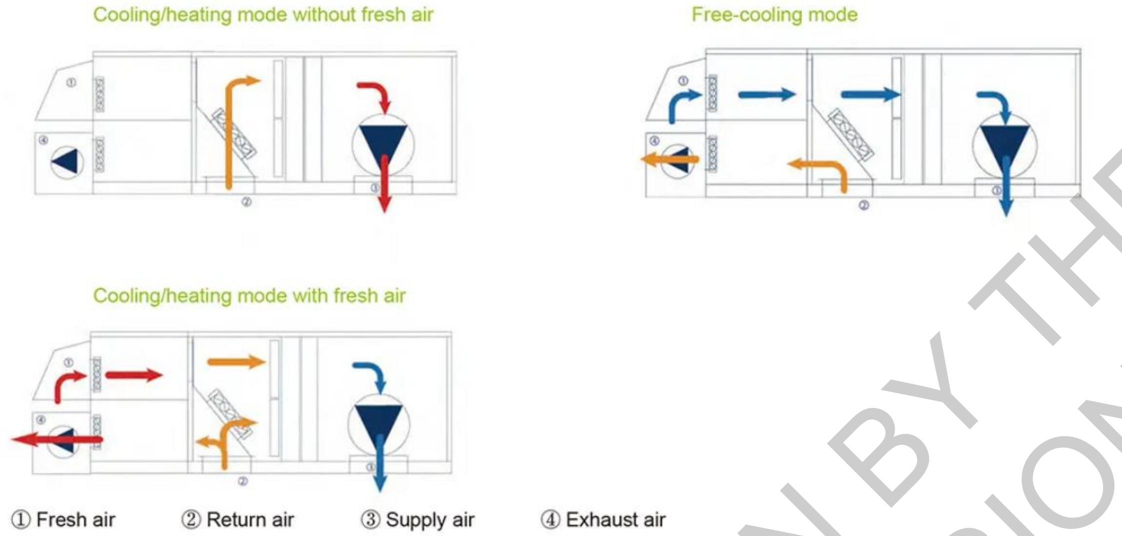

Figure: Free cooling mode of an HVAC system from https://www.waterchiller.pl/free-cooling-rooftop-packaged/57012818.html

Free cooling can be applied to **residential houses, hotels, town halls, and even data centres**. **In some countries** the use of recuperators or free-cooling systems is **mandatory, to increase the efficiency of the building.**

The benefits are the “free” source of energy, easy maintenance (just cleaning up the filters), and the system can take effect when the difference between the outside supply and return temperatures is as little as 1°C.

With the implementation of Free Cooling systems operation costs are reduced, but just in some cases when the climatic conditions are favourable. Although costs are reduced there is still associated cost due to fans (which need to ensure the pressure in the ducts and heat exchangers to allow the fluid/air to move), but it is low compared to a system without free cooling that always operates with mechanical ventilation.

CO-BENEFITS	With free cooling systems, the cooling needs are reduced so the energy consumption is lower, and this is translated to a lower emission factor due to energy savings in a system that has it. Free cooling systems are in fact really simple, it allows the reduction of the internal air temperature without needing compressor systems or heat exchangers, so it results in the improvement of the air quality with fresh outdoor air and without noise pollution due to not having any "mechanical moving parts" and also integrating an effective sound attenuation system to improve the quality of life. Great applications in spaces where the cooling demand implies a great consumption, like for example data centres.
KEYWORDS	It can be applied in air-conditioning systems (HVACs), with or without heat pumps, or photovoltaics.
EXTERNAL LINKS	• https://www.nortekair.com/wp-content/uploads/2017/01/Free-Cooling-Concepts-for-Data-Centers.pdf • https://e3p.jrc.ec.europa.eu/file/2148/download?token=fOQRkXC6 • https://www.idae.es/uploads/documentos/documentos_09_Guia_tecnica_ahorro_y_recuperacion_de_energia_en_instalaciones_de_climatizacion_dd65072a.pdf • https://blog.passivehouse-international.org/summer-comfort-passive-house/

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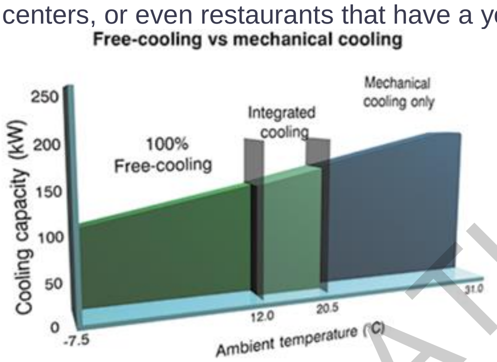
Freecooling opportunities (Air-to-air heat exchangers)	
PRE-CONDITIONS & ENABLING CONDITIONS	***Climate and geography:*** Freecooling depends on the outside air temperature that must be lower than desired temperature, so it's better suitable for climates with a large difference between minimum and maximum daily temperatures, or diurnal swing. For humid climates it has to be considered the increase in the humidity levels inside the building, which could reduce thermal comfort or even lead to mold growth (ATECYR, 2012). ***Technical aspects/ infrastructure:*** The system depends on the outside temperature, so will achieve greater efficiencies during cold seasons (100% freecooling) and during mid-season when the air will be partially cooled by the compressor. As shown in the figure below. The system is more suitable for locals with higher full load hours as industries, data centers, or even restaurants that have a yearly constant cooling load.  *Figure 1: Freecooling capacity. Source: Airdale* This equipment has easy maintenance based on replacing the air filters, and is focused on avoiding microbial growth over dirty filters or stagnant water in drain pans. ***Policy and regulatory/legal framework:*** Freecooling is included as best practice in The Code of Conduct for Data Centres, a voluntary initiative managed by the *JRC* to reduce energy consumption. It also appears as a solution in the EPBD in order to increase the liveability of enclosed spaces. ***Project governance and implementation modalities:*** This technology has been included in European projects and national regulation due to the high impact of the space cooling needs, according to (IEA, 2018) air-conditioning accounted for nearly 20% of the total electricity demand in buildings worldwide and will almost triple by 2050. Some examples are Building Energy Codes, Minimum Energy Performance Standards (MEPS) and labelling.
CONSTRAINTS/ BARRIERS for implementation	***Climate and geography:*** It is not suitable for every location, the humidity must be considered, also in humid regions an enthalpy controller is needed to reduce measurement errors, which requires a higher investment and higher maintenance requirements. Enthalpy controllers include a thermostat and humidity sensor and help achieve greater savings (10-20%) compared to standard thermostats (ATECYR, 2012). Other specific considerations regarding the temperatures of operation are that the system can become economically unfeasible when the heat exchanger works in range with very low temperature differences and that in cold climates, in order to avoid freezing onto the evaporator surfaces, the air ventilation shafts set-point temperature must be equal or greater than 5°C (ReUseHeat, 2022). ***Policy and regulatory/legal framework:*** Current planned policies to increase the access to cooling systems would have limited effect, the access to cooling systems can be targeted as a social issue and used only by 8% of the people living in warm regions.

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Freecooling opportunities (Air-to-air heat exchangers)	
	This solution requires coordination with national governments to be properly enforced alongside with incentives it is needed the share of expertise and knowledge. Policies could integrate a local approach, where investment decisions are taken and implemented; to increase their effectiveness (IEA, 2018). ***Project governance and implementation modalities:*** Even if there is growing interest in programmes to increase energy efficiency in the building sector, efficient technologies and retrofitting measures are expensive. The economic viability of these measures, especially for renovating existing buildings; is strongly dependent of the inherent inefficiencies (IEA, 2018).
INSTRUMENTS/ Processes for implementation	• Governance EU Climate Neutrality Framework: https://netzerocities.app/resource-1728 • Loans for Energy Efficiency (EE) could include this solution as a way for improving EE in buildings https://netzerocities.app/resource-1648 . Same applies to Blended finance for Energy Efficiency (EE) https://netzerocities.app/resource-1658 • Building Renovation Passport (BRP) could include this solution as example. https://netzerocities.app/resource-1748 • One-stop-shop for building renovation https://netzerocities.app/resource-1913 • User Engagement for Energy Performance Improvement https://netzerocities.app/resource-1498
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	In humid climates it will need more maintenance and a de-humifier to reduce the humidity content and avoid mold growth (NANOCOOL, 2016).
IMPACTS (Indicators & DNSH)	***Energy savings:*** The pre-cooling of the inlet air can reduce the compressor operation, depending the outside temperature it can partly operate or even not been operated at all. This means a reduction in the energy consumption and a reduction of GHG emissions an energy cost. On data centers some freecoolers have shown energy savings up to 70 % versus conventional mechanical refrigeration (Nortek, 2015). ***Health:*** Freecooling systems improve Internal Air Quality (IAQ) thanks to the renovation with oxygenated fresh air and control of the humidity content, avoiding the so-known "Sick Building Syndrome" (NANOCOOL, 2016). ***Thermal comfort:*** The use of free-cooling systems reduces the operation of conventional compression air conditioning systems, which match the latent cooling loads by reaching the dew point of air. So, with conventional cooling systems sometimes the outlet air is too low for thermal comfort and needs to be re-heated, increasing even more the energy consumption (NANOCOOL, 2016).
	DNSH: ***Climate change mitigation*** This activity leads to a significant greenhouse gas emission reduction on a lifecycle basis ***Climate change adaptation*** This activity will be more necessary for the liveability of future urban scenarios based on the forecasted future climate crisis. ***Pollution prevention and control*** This activity leads to a reduction of electricity consumption, and consequently to a reduction of emissions

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Freecooling opportunities (Air-to-air heat exchangers)	
Additional information from CASE STUDIES	***BODENTYPEDC* data center prototype in Sweden (2019).** Data centers are characterised for having a high and constant cooling consumption, to evacuate the excess heat produced by the computers. In this prototype there is a freecooling coupled with an evaporative cooling system, to reduce the overall consumption. In Northern Europe evaporative cooling can provide temperatures below 25˚C all year round and achieve 99.9% ASHRAE Class 1 compliancy. ***Integrated heating, ventilation and natural air conditioning in an office building*** An office building was refurbished and now applies natural air conditioning principles, supplying and distributing the air through the cavities of the hollow floor instead of the existing air ducts. Now performs freecooling on summer nights, letting the fresh air into the building and refreshing the concrete floor; and even (air) floor heating in winter with heat recovery from the warm air rejected during the cold season. ***CommONEnergy* demosite in Mercado del Val, Valladolid (SP)** This historic marketplace was refurbished and included passive measures to increase energy efficiency. The system includes three reversible ground to water geothermal heat pumps (for DHW and cooling in summer) and also an Air Handling Unit (AHU), which can operate in free-cooling mode and with a heat recovery efficiency of more than 65%. The cooling production for all the markets is centralised, and the exhaust heat produced on the heat exchanger, is recovered for pre-heating the water circuit for space heating in winter. With the refurbishment and installation of efficient lightings and HVAC equipment, savings on final energy are 75%, being lighting and cooling the ones with higher savings, both above 80%.

3.1.18 Sewage heat recovery via pump system

- Authors: **CARTIF**
- Knowledge Repository link: https://netzerocities.app/resource-738

Sewage heat recovery via pump system
A sewage heat recovery via pump system is designed to **withdraw heat from warm wastewater (12-15°C)** through heat exchangers, in a closed loop to avoid mixing; preheating cold tap water, and reducing heating demands and fossil fuel consumption. Sewage heat recovery systems can be implemented in different scales: **in-house** energy recuperation (small-scale), energy recovery from raw wastewater **in sewers** (medium scale) or for cleansed wastewater **after the sewage treatment plant** (large scale). Small scale systems are used to pre-heat domestic hot water and space heating demands, medium and large scale can sell heat to a District Heating and Cooling Network (DHCN). The system **needs to be implemented with heat pumps** to raise its temperature for consumption. The benefits are its simple and robust design with a long-life span, and that is an accessible low-heat source of energy, with great potential (5% of the heat demand of cities). Other benefits are that it allows coupling with RES sources like solar thermal or other waste heat sources like industrial heat or exhaust air recovery and that it's compatible with a low-heat DHN due to the fact that the points of source heat are the same as the points of consumption so the transmission losses are reduced.

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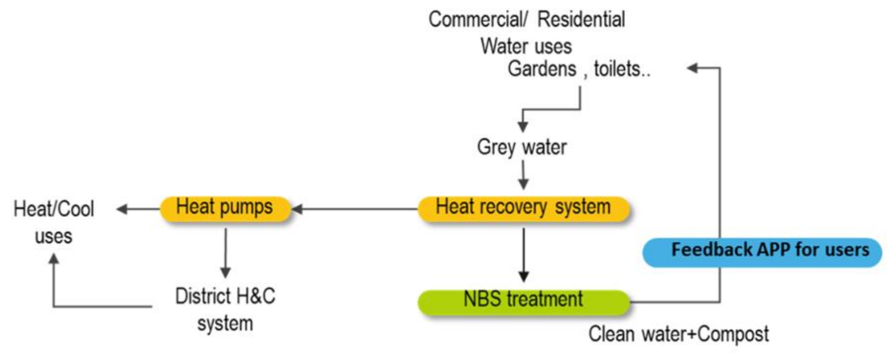
Sewage heat recovery via pump system



Source: Cartif elaboration

The main drawbacks are economic for both cases, but especially for the sewer scale plant because of the expensive civil works required for a district heating network and greater installations; along with soiling by the wastewater and the big maintenance effort. Furthermore, at the building scale there might be limitations on space availability, it needs about 2 m of height; and the pumping consumption could be avoided using a passive configuration locating the tank in the lowest point of the sewage system.

CO-BENEFITS	With the sewage heat recovery, the hot water demand could be reduced up to 20% by raising its temperature by 10 degrees, that amount of savings can be translated to economic savings and reduction of GHG emissions, related to fossil fuel consumption. The system promotes **energy efficiency** by heat recovery and **circularity** (Better energy efficiency)
KEYWORDS	This innovative solution **can be coupled with low district heating**, due to the fact that the source of heat is located really close to the points of consumption, reducing the heat transmission losses. If combined with other solutions (like water purification technologies or water treatment, with nature-based or other), it could also lead to better water management (as the clean water post-treatment can be used for gardens or toilets in the same building).
EXTERNAL LINKS	LINKs to external catalogues • http://wasenco.com/ecowec-hybridivaihdin_ottaa_lammon_talteen_jatevedesta/ REFERENCES • https://www.ecowec.com/ • http://eu-gugle.eu/de/aachen-flushes-heat-out-of-the-sewage-canal/ • https://www.kasag.com/en/renewable-energies-systems-plants-heat-exchanger-heat-from-wastewater/ • https://www.uhrig-bau.eu/en/division/heat-from-wastewater/technology/ • https://www.sciencedirect.com/science/article/pii/S1876610218305071/pdf

Sewage heat recovery via pump system	
PRE-CONDITIONS & ENABLING CONDITIONS	***Climate and geography*** Sewage heat is an accessible low-heat source of energy that offers great thermal stability throughout the whole year within a range of (8-15˚C). ***Urban form and layout:*** To make heat recovery feasible it must be installed in places with high density of population, according to the IEE project 'Stratego' for big cities with more than 10,000 inhabitants and coupled with large heat pumps it could cover about a 5% of the heat demand.

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Sewage heat recovery via pump system	
	This solution also requires specific infrastructure like existent District Heating and Cooling Network (DHCN), which has to be close to the points of consumption, within a radius of 300 metres, but it is preferable around 150m. (H.Erhorn, 2018) ***Technical aspects/ infrastructure:*** Wastewater can be used to produce both heating and cooling as base thermal load, needing back-up systems to cover peak loads. This system requires two different and separated loops and great maintenance in order to separate solid substances on the sewage flow. Existent wastewater heat pumps worldwide rate from 10 kW to 20 MW (LOWUP, 2020). ***Policy and regulatory/legal framework:*** Waste heat from sewage water has been defined as “ambient energy” in *The new Renewable Energy Directive,* and thus as part of the renewable sources. In general, there are no regulatory restrictions for the supply of waste heat into DH network, but since sewage water channels and wastewater treatment plants are public infrastructures, there are specific regulations regarding its performance and safety in order to ensure that their operation will not be affected (Euroheat & Power, 2020). ***Economic and social context:*** There is little awareness regarding waste heat sources, especially from unconventional ones. It would be necessary to increase the public awareness about waste heat recovery benefits in order to increase its presence onto national and municipal renovation plans (Euroheat & Power, 2020).
CONSTRAINTS/ BARRIERS for implementation	***Technical requirements:*** It is a low-heat source, it requires high density of population and to be closer to the points of consumption, which reduces its application for large-scale plants, since wastewater treatment plants and industries are usually located far from the points of heat consumption. It can produce both heating and cooling but needs to be coupled with backup systems to cover the loads like Heat Pumps. Sewage heat recovery is a technical solution that already exists in the market but shows low-replication potential, mainly due to lack of experience and little awareness (consumer, manpower and municipalities). There are only around 120 systems all over Europe and 500 in the world, being more common in countries where district heating is well-developed, which makes sense since for large-scale applications the system requires existent DHCN infrastructure (Euroheat & Power, 2020). ***Costs:*** In general, this solution has high costs of operation due to maintenance and cleansing requirements that depends on the scale of the system and the wastewater quality. For small-scale installations space requirements and pumping costs have to be considered. ***Economic and social context:*** There is little awareness of waste heat and can be difficult to sell as a sustainable product to end-users and customers, and even more if the waste heat is related to a fossil fuel driven activity. The interest and know-how of a ‘waste heat owner’ for supplying waste heat to DH networks can be rather low since it is not part of their core business. The benefits from selling waste heat usually don’t match the investment and operation costs. Furthermore, waste heat owner could also need to change their processes due to the installation of heat exchangers, which could negatively affect their main activity. For example, in pharmaceuticals, industrial processes and waste heat recovery

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Sewage heat recovery via pump system	
	systems are decoupled, in order to not affect manufacturing (Euroheat & Power, 2020). ***Regulation:*** Waste heat potential is less straightforward to identify and plays a minor role in national decarbonisation strategies. In addition, waste heat from sewage water channels and wastewater treatment plants have specific regulations that might result in an unbalanced treatment of the different waste heat sources when it comes to implementation. Waste heat owners and DHC operators usually do not have contact with each other which limits their dialogue and there is a lack of standardised contracts which increases the project's complexity (Euroheat & Power, 2020).
INSTRUMENTS/ Processes for implementation	• Governance EU Climate Neutrality Framework: https://netzerocities.app/resource-1728 for demand and GHG reduction, thanks to the use of waste heat sources. • City water resilience assessment: https://netzerocities.app/resource-1738 referred to the treatment of waste water and the final quality and temperature level of the outlet flow previous to return to the natural environment. • Integrated climate plans for cities: i.e.: SECAPs: https://netzerocities.app/resource-1698 large-scale systems uses public owned infrastructures and could require big civil works at city level. • Loans for Energy Efficiency: EE: https://netzerocities.app/resource-1648 • Blended finance for Energy Efficiency: EE: https://netzerocities.app/resource-1658 • Platform for Enhancing Multi Stakeholder Dialogue to Implement NBS across EU: https://netzerocities.app/resource-1628 waste heat owners and DHC operators do not usually have contact with each other and could result into communication problems.
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	The main drawback is the **maintenance**, as if not done it can cause odours. Sewage heat is a low-heat source that still **requires of backup** systems to increase or reduce its temperature level to cover thermal heating and/or cooling loads, which results in additional costs. Waste heat recovery is often done on a case-by-case basis, there is no standard solution due to very individual and site-specific boundary conditions, as well as the limited number of real-life case studies, especially for unconventional waste heat sources. This results in high efforts to plan, design and operate systems. Consequently, the engineering and instrumentation efforts and connected costs are relatively high compared to other heat sources (Euroheat & Power, 2020). For water fauna, the cooling of the downstream of wastewater treatments plant is even desirable. In the same aspect the use of this source for cooling purposes could be limited because the increase of the downstream temperature above levels defined in water protection regulation (Schmid F. , 2008).
IMPACTS (Indicators & DNSH)	***Emissions:*** In Aachen district the new system with sewage heat recovery coupled with brine-to-water heat pumps saves about 264 tonnes of CO_2 emissions each year. The sewage heat recovery in ReUseHeat demo in Nice has expected savings of 4.000 tonnes of CO_2 per year, for an installed capacity of 19 MW for heating and 15 MW for cooling. ***Energy savings:*** There is a demand reduction since less energy is required to cover thermal loads. To reduce even more the final consumption, it requires efficient backup systems such as booster HPs, which could use green electricity as PV on-site production and constitute a zero-emission system.
	DNSH:

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Sewage heat recovery via pump system	
	Climate change mitigation This activity leads to a significant greenhouse gas emission reduction on a lifecycle basis ***Sustainable use and protection of water and marine resources*** This activity could be beneficial for bodies of water, including surface water and groundwater, or to the good environmental status of marine waters. ***Circular economy*** This activity promotes the circularity of the thermal energy use. ***Pollution prevention and control*** This activity leads to a reduction of electricity consumption, and consequently to a reduction of emissions. ***The protection and restoration of biodiversity and ecosystems*** This activity can help in maintaining optimal thermal conditions for water habitats and species.
Additional information from CASE STUDIES	**EU-GUGLE pilot buildings in the Aachen (DE) North district**: The system is composed of two 220kW brine-to-water heat pumps to boost the temperature of the sewage canal, whose values throughout the year are contained between 12-15°C, reaching sometimes 20°C. In Aachen, the total cost of the investment amounts to €780,000 but will enable the city to save 264 tonnes of CO_2 emissions each year. **Neckarpark Stuttgart (DE) urban district:** The DHCN grid has been installed to supply 450 residential NZEBs. The network includes heat recovery from a wastewater with an installed capacity of 2.1 MW, about 838 kW/K of heat extraction capacity from a flow which does not drop below 12 °C even during cold periods. This area is composed of NZEBs so in this case the low-heat source proves to be more efficient than traditional district heating involving high supply temperatures. **ReUseHeat demosite of "Grand Arenas district" in Nice (FR):** This European project implemented heat recovery from the sewage system with temperatures between 25-30°C in summer and 13-8°C in winter; to a low temperature DHN. With an installed capacity of 19 MW for heating and 15 MW for cooling, the expected annual thermal energy production is 17 GWh/year and 22 GWh/year respectively.

3.1.19 Smart street lighting – Humble Lamppost

- Authors: **CARTIF**
- Knowledge Repository link: https://netzerocities.app/resource-266

Smart street lighting – Humble Lamppost
Street lighting is a fundamental service provided by municipal governments. It ensures safe transport, makes cities safer, and allows cities to look their best. Smart street lightings are characterised by the fact that the individual light point not only fulfils the **function of the lighting**, but also offers **additional services for citizens**. An increase in the scope of functions offers the linking of services and makes further services possible, such environmental monitoring (noise and air quality), or public Wi-Fi improvement among others.

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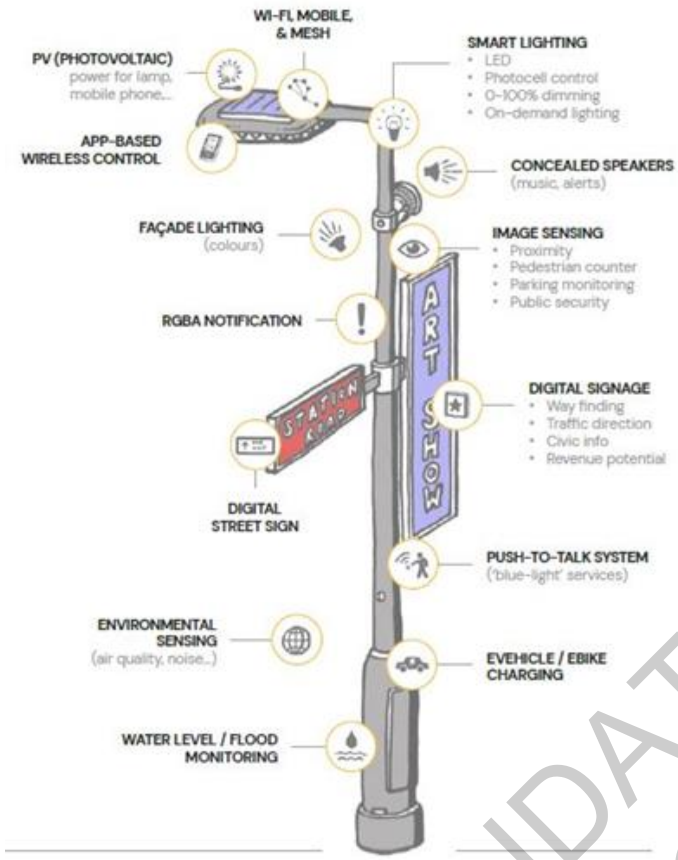
Smart street lighting – Humble Lamppost



Smart Street Lighting with additional services. Source: Humble Lamppost Whitepaper report

LEDs are the ideal luminaire for intelligent street lighting. The properties of the defined light direction and the variations in luminous intensity and light colour are main improvements compared to former illumination. Smart lighting also offers new opportunities of **modularity and adaptability** for lighting itself, enabling an adaptation to temporal needs and practices through the night, weeks, seasons, etc., as well as to take into account challenges related to biodiversity conservation.

By introducing a **smart street lamp concept**, it is able to save energy and maintenance costs (**remote management system**), and reduce CO_2 emissions, while improving public safety. Possible **additional services** for public lighting are listed below:

- Wi-Fi
- **Traffic Sensors** (Bikes/ Pedestrians/ Cars)
- Vehicle/ Bicycle Charging Station
- **Environmental Sensors** to measure air pollutants, noise pollution or weather information
- **Adaptive Lighting**: Light is only provided when needed and it is controlled according to the application without impairing traffic safety. It considers not only a switching on/off of the light point according to **people detection**, but also light levels variation and an optimisation of the communication between groups of light poles to obtain a moving light following the **user trajectory**.

CO-BENEFITS	Expected benefits are related to **reduce the energy needs** of the public lighting due to a higher efficient system, leading to a **reduction in GHG emissions**, while enhancing **stability of the urban infrastructure**. It also contributes to **improve air quality** thanks to the lower emissions, and a **reduction of road danger** thanks to the better street lighting. It can also benefit the **attractiveness of the cities**, higher **citizen connectivity** (smart lighting - WiFi) and a **reduction in future maintenance costs**.

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Smart street lighting – Humble Lamppost	
KEYWORDS	Smart street lighting can be integrated with EV or e-bikes charging infrastructure, as well as it can form a bundle with other urban solutions at district or city level (e.g. Nearly zero/ Positive Energy District).
EXTERNAL LINKS	Reference of the text: • Humble Lamppost Whitepaper report: https://smart-cities-marketplace.ec.europa.eu/media/248. It includes Case Studies from Barcelona, Spain; Copenhagen, Denmark; Munich, Germany; Los Angeles, USA; City of Westminster, London, UK; Singapore • Exploiting the 'humble lamp post', a kick start to smart city – A guide for city leaders • La renovation de l'Eclairage (Smart Building Alliance, 2020)
EXAMPLES	mySMARTLife intervention in Hamburg: • Design and implementation of adaptive lighting concept • Design and implementation of the humble lampposts concept Hello Lamp Post concept in Bristol, UK, for citizen engagement

Smart street lighting – Humble Lamppost	
PRE-CONDITIONS & ENABLING CONDITIONS	***Urban form and layout:*** It is very relevant to take the urban form and density, as well as mobility paths into account especially for the implementation of street lighting including functionalities such as traffic sensors, cameras, charging stations, Wi-Fi, 5G, as well as if adaptive lighting are needed. ***Technical aspects/ infrastructure:*** It is needed to properly select the most appropriate type of smart urban lamppost, according to the needs of the city (cross-departmental, cross-sectoral, benefits are not only related to lighting) and what the different models offer. For the implementation, it is needed to establish the plan to replace and update the lighting stock at volumes that will not fully engage the supply base. It is crucial also, for the feature of monitor or gathering data (e.g. mobility data, environmental data: air quality), that communication protocols, data gathering among other things are well defined. ***Funding and financing:*** Business model and financing options to be checked-out before the implementation, they can help the team in making decisions about this that deliver the scale and potential that it can. A good strategy can be to have a plan that every time a lamppost is broken or needs to be replaced, the smart lighting humble lamppost is installed, which reduces the payback period significantly (as you need to install a new lamppost anyway). ***Project governance and implementation modalities:*** It is **needed an integrated city approach** (Smart City strategy), since the smart street lighting has a lot more potential functions that just providing light. E.g. data strategy, mobility plans (it may be used for improving pedestrian and bicycle connections in addition to charging stations feature), public safety and security (e.g. traffic safety strategy: lights dim in some areas according to a schedule, but sensors enable lights to brighten when cyclists approach unsafe road junctions), health strategy (e.g. they can be used to implement crowd control measures).
CONSTRAINTS/ BARRIERS for implementation	**Barriers of collaboration locally between departments** (lighting, roads, health, etc. – all of whom could stand to benefit), between cities typically locally; and **between city-clusters** on an international basis. As well as between public sector, industry and potential financiers – all of whom view the opportunity from very different perspectives.

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Smart street lighting – Humble Lamppost

Other barriers are related to the **ownership** of lampposts and operational contracts, due to the fact that most of the cities owned their lampposts, and following questions (among others) should be solved in advance: 'Who provides the power to the lamppost?', 'Who is paying for the lights?', 'Who is going to pay for all of it?'

Some cities (such as Barcelona) has a number of specially **protected heritage sites**, so they need to ensure that the technology they deploy in public space is not in conflict with the landscape (lamppost designs need to blend into the landscape, e.g. without lots of wires hanging out…).

INSTRUMENTS/ Processes for implementation

- User Engagement for Energy Performance Improvement : https://netzerocities.app/resource-14988
- Loans for Energy Efficiency (EE): https://netzerocities.app/resource-16488
- Blended finance for Energy Efficiency (EE): https://netzerocities.app/resource-1658
- Integrated land use and urban planning with energy and climate: https://netzerocities.app/resource-1678
- Integrated land use planning and urban space management with mobility planning: https://netzerocities.app/resource-1688
- Smart Readiness Indicator (SRI): https://netzerocities.app/resource-1758
- Mobility Management: https://netzerocities.app/resource-1768

DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation

In the case of Copenhagen, they set up incentives to lower energy consumption with a city goal for 70% reduction, but these outdo incentives use the IoT network installed in the lampposts as using the network drives up consumption.

If new smart lamppost looks like the conventional city lampposts and uses the same material, this will **keep costs low**, as if the construction is the same as every other lamppost, we can use the same machines to build them and have no problem with standards or power supplies in the ground. It was done this way in Munich. Yet, the installation of these smart lampposts is really expensive.

Time: In Munich, it took them one and a half years to install this infrastructure from the moment they planned it to installation. The construction took a while to do.

IMPACTS (Indicators & DNSH)

Energy efficient LED street lighting can offer substantial (up to 50%) savings on energy consumption.

The smart street lighting system uses sensors on light poles, which enables them to detect. Wireless movement network to connect sensors, collect data and control remotely; It can generate more than 70% secondary energy saving.

CARBON EMISSIONS ABATEMENT FROM CONNECTED CITIES[21] (tCO_2e/year)

	UK	Germany	Spain	France	USA	Europe
Connected Cities	435,000	498,000	226,000	383,000	1,990,000	3,018,000
Parking space monitoring	9,000	12,000	6,000	12,000	260,000	74,000
Smart bins	20	20	10	10	70	100
Street lighting	108,000	42,000	8,000	5,000	31,000	202,000
Traffic congestion management	38,000	61,000	40,000	45,000	212,000	403,000
Traffic congestion monitoring (road signs)	149,000	204,000	92,000	170,000	372,000	1,281,000
Traffic congestion monitoring (traffic lights)	131,000	179,000	81,000	150,000	1,116,000	1,057,000

Carbon emissions abatement, source: GSMA

DNSH:

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Smart street lighting – Humble Lamppost	
	Climate change mitigation: The construction/implementation of the lamppost can lead to a significant greenhouse gas emissions on a lifecycle basis ***Circular economy:*** Second life materials use for the construction of the lamppost are highly recommended, so as to not harm this activity.
Additional information from CASE STUDIES	In some cases, smart streetlighting can give rise to concerns among city residents, resulting in them not being supportive. They may have privacy concerns related to the combination of other applications with smart streetlighting (e.g. security cameras). To counteract this, cities are consulting and engaging with residents; for example, Eindhoven in the Netherlands involved residents in the development of its smart streetlighting project, giving them the ability to suggest functionalities and preferences.

3.1.20 Low-GWP heat pumps

- Authors: **Tecnalia, CARTIF**
- Knowledge Repository link: **https://netzerocities.app/resource-748**

Low-GWP heat pumps
Heat Pumps (HP) are conversion devices able to transfer heat from a lower temperature heat source into a higher temperature heat sink. There are several types of HP (electricity compression heat pumps, gas driven HP, heat driven HP, etc.), the most common and efficient the electrical ones. When electricity comes from renewables, it can be considered green. Due to its versatility and high energy efficiency, the development of HP technology will be **crucial in this transition toward electrification and decarbonisation of cities.** Heat pumps have **traditionally used refrigerants with high global warming potential (GWP),** being potentially releasers of greenhouse gases to the atmosphere (through leakages). The **use of low-impact refrigerants is a need already covered by regulations, and expected to increase in the future. In fact, F-Gas regulation [2] imposes a series of restrictions on the use of refrigerants until 2030, phasing out some higher GWP refrigerants soon,** which paves the way for the **use of natural refrigerants (e.g. CO_2, propane, and ammonia).**

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Low-GWP heat pumps

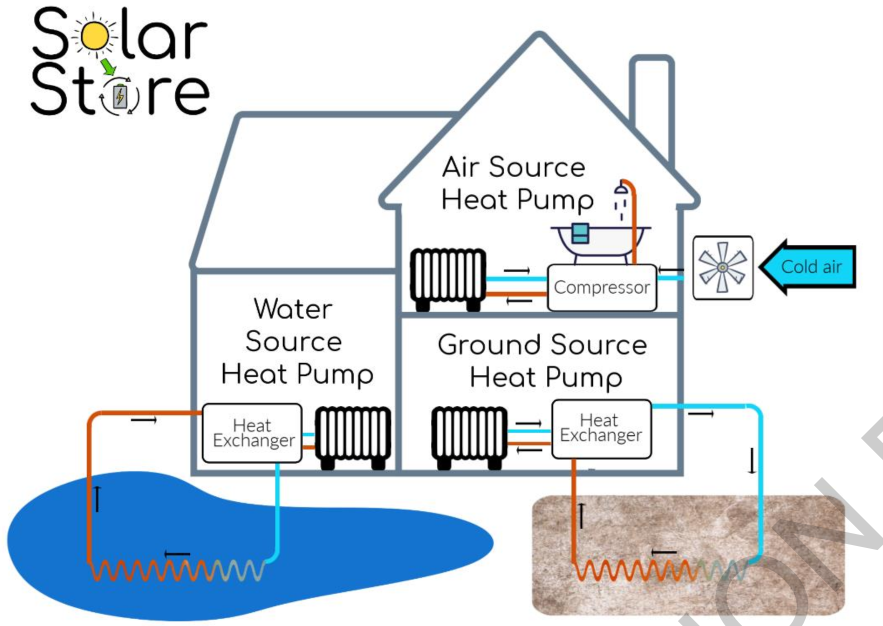

Figure: an overview of heat pumps types (https://solarstore.biz/heat-pumps/)

Heat pumps have characteristics that make them **very interesting for using it in many applications,** such as near-zero energy buildings (NEZB), district heating and cooling networks (distributed in every building or central heat pumps), positive energy districts, energy communities, and by **combination with other sources (geothermal, solar, etc).** NZEB is designed to have a very low energy demand, which is largely covered by energy from renewable sources, including the self-production of renewable energy. In this context and considering residential energy consumption, the HP is imposed as a technology for the future.

New **developments of HPs are being raised for decarbonisation of industries, electrification of district heating and cooling networks, utilization of waste heat (to upgrade it and inject it in networks) and for utilizing both sinks (condenser and evaporator) at the same time (using dual source heat exchanger**, see example below).

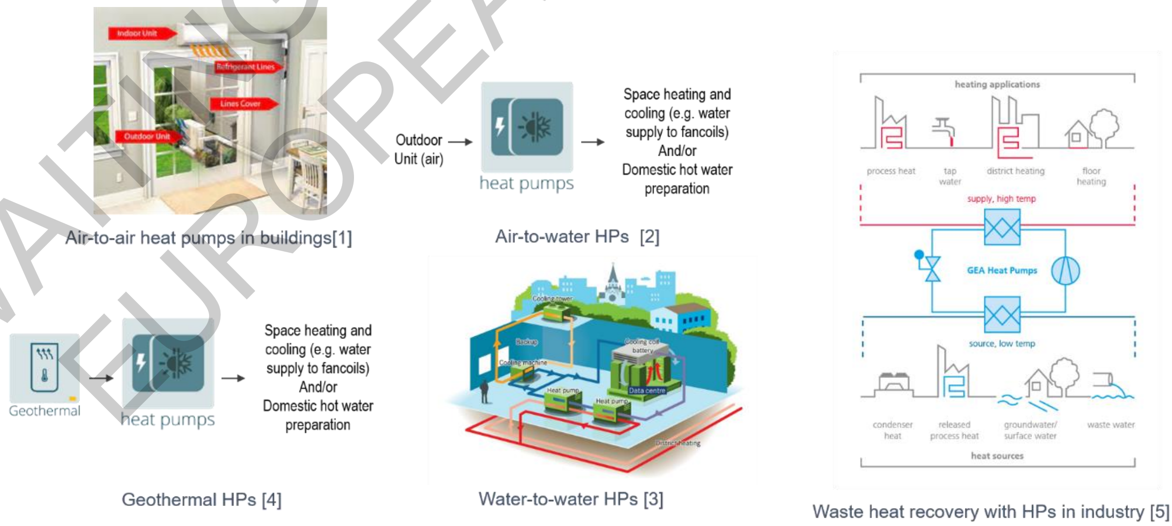

Figure: an overview of heat pumps applications

CO-BENEFITS	The use of heat pumps with low-GWP fluids contributes to lower GHG emissions due to refrigerant losses in HVAC equipment. District or local cooling-heating networks could possibly benefit by the use of two source/sinks, as a method for

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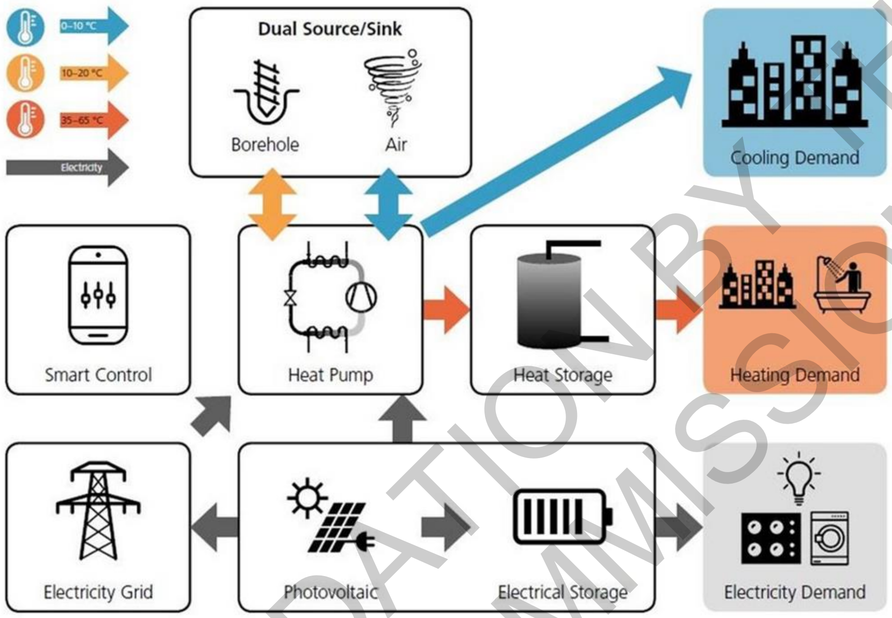
Low-GWP heat pumps	
	compensating thermal rings which could be decompensated because unexpected demands, and so on.
KEYWORDS	Direct: Dual-source, heat exchanger, heat pump, low-GWP fluids, natural refrigerants, hybrid systems, district heating and cooling networks, positive energy districts, energy communities, nearly zero energy buildings  *Figure: Heat pump combination*
EXTERNAL LINKS	• [1] https://www.climateworks.ca/heating-ottawa/heat-pumps/ductless-heat-pumps/ • [2] [4] own elaboration • [3] https://www.iea.org/articles/heat-pumps-in-district-heating-and-cooling-systems • [5] https://www.gea.com/es/articles/heat-to-cool/district-heating.jsp ***EU projects:*** • TR-HP Project: https://www.tri-hp.eu/ (trigeneration systems based on heat pumps with natural refrigerants and RES) • SunHorizon project: https://sunhorizon-project.eu/ (solar-driven heat pumps) • REWARDHeat: use of heat pumps in district heating and cooling networks https://www.rewardheat.eu/en/ • Use of heat pumps in PEDs: https://smartcity-atelier.eu/about/lighthouse-cities/bilbao/

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Low-GWP heat pumps	
PRE-CONDITIONS & ENABLING CONDITIONS	As pre-conditions the following ones may be representative of most usual ones but without being an exhaustive list: • ***Regulatory support***: Government policies and regulations that support the use of low GWP refrigerants and incentivize their adoption. • ***Availability of low GWP refrigerants***: Their existence and compatibility with existing HVAC systems are critical factors in the successful implementation of this solution. • ***Technical expertise***: Requirement of qualified professionals who are trained in the installation and maintenance of low GWP heat pumps.

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<table>
<tr><th colspan="2">Low-GWP heat pumps</th></tr>
<tr><td></td><td>• Cost-effectiveness: Must be competitive compared with traditional heating and cooling systems to encourage their adoption.
• General awareness and collaboration between stakeholders is needed.</td></tr>
<tr><td>CONSTRAINTS/ BARRIERS for implementation</td><td>Innovation in the field of low GWP heat pumps continues for different solutions. There are, nevertheless, some obvious constraints and barriers for wider implementation. Among other:
• Generally speaking CAPEX is higher than in the case of traditional heating and cooling systems. And OPEX is also higher due to availability of these refrigerants. This makes that payback may result larger than for other technologies.
• The use of low GWP requires specialized technical knowledge. The pertinence of selected refrigerant considering the capacity, temperature level, etc. must be analysed in each case and this may become a constraint in some cases.
• There may be performance limitations compared to traditional refrigerants which can limit their effectiveness in extreme weather conditions.
• Regulatory uncertainty: Changes in regulations related to refrigerants and energy efficiency standards can create uncertainty and may impact the viability of low GWP heat pumps.</td></tr>
<tr><td>INSTRUMENTS/ Processes for implementation</td><td>Most interesting instruments are the ones that can help to finance the installation of these solutions. From the list of instruments in NetzeroCities we can consider:
• Loan for Energy Efficiency (https://netzerocities.app/resource-1648) to provide soft funding
• Blended finance for Energy Efficiency (https://netzerocities.app/resource-1658)</td></tr>
<tr><td>DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation</td><td>While low GWP heat pumps offer many benefits, there are also some potential drawback to their operation, as for example:
• Lower efficiency in extreme temperatures
• Safety concerns: Some low GWP refrigerants, such as propane are flammable and may require additional safety precautions during installation and maintenance.
• Refrigerant leaks: Like any refrigerant system, leaks may happen which can result in the release of greenhouse gases and other pollutants into the atmosphere.
• There are compatibility issues as not all low GWP refrigerants are compatible with all HVAC systems, which can limit the availability of certain types of GWP heat pumps in some regions.
• They require more frequent maintenance which increases OPEX over time.
It is important to note that many of these drawbacks can be mitigated through proper installation, maintenance, and safety procedures.</td></tr>
<tr><td>IMPACTS (Indicators & DNSH)</td><td>Same indicators as for regular heat pumps with special attention to values of GWP. The other indicators to be considered are:
• Energy consumption: As total energy usage, energy intensity (energy usage per unit of output) or energy cost
• Energy savings: As total energy saved, energy savings as a percentage of baseline consumption or energy savings per unit of output
• Greenhouse Gas Emissions
• Cost savings
• Etc.
But also, specific KPIs such as equipment uptime, reliability, maintenance cost, etc.</td></tr>
<tr><td></td><td>DNSH:
Climate change mitigation | This activity leads to greenhouse gas emission reduction on a lifecycle basis</td></tr>
</table>

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Low-GWP heat pumps		
	Climate change adaptation	n.a.
	Circular economy	The use of low GWP heat pumps contributes to a circular economy by recovery waste heat and renewable sources.
	Pollution prevention and control	The use of low GWP prevents harmful impacts in emissions.
Additional information from CASE STUDIES	• https://cordis.europa.eu/project/id/308816/reporting • https://doi.org/10.1016/j.enconman.2020.113752 • https://doi.org/10.1016/j.rser.2020.110571 • https://doi.org/10.1016/j.jclepro.2023.136773 • https://doi.org/10.3390/su15064973	

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3.2 Energy Generation

- **Knowledge Repository: Energy Generation:** https://netzerocities.app/resource-338

Table 4: Energy Generation solutions

Energy Generation		Section
RES electricity and thermal energy generation	Distributed wind	3.2.1
	Micro-hydropower generation in urban water networks	3.2.2
	Geothermal energy	3.2.3
	Co-generation systems	3.2.4
	Sustainable biomass and biogas power	3.2.5
	Fuel cells	3.2.6
Energy recovery	Waste heat recovery in district heating networks	3.2.7
Energy and E-fuel storage	Electricity storage: Chemical storage	3.2.8
	Thermal Energy Storage	3.2.9
	Seasonal storage (pits, dwells, etc.)	3.2.10
Infrastructure	From 3G to 5G District Heating and Cooling networks (generation to substations)	3.2.11
	Renovation of DH&CN (1G and 2G)	3.2.12
	Microgrids	3.2.13
Smart solutions	Energy management techniques	3.2.14

3.2.1 Distributed wind

- Authors: **VTT**
- Knowledge Repository link: **https://netzerocities.app/resource-768**

Distributed wind

Distributed wind consists of wind turbines connected to the distribution level of the electric grid, to serve either on-site loads or local loads in the same grid. Use cases are utility (cooperative or publicly owned), industrial, residential, institutional, governmental, commercial, or agricultural. The most common grid applications are grid-connected microgrids, isolated grids, and remote off-grid [1].

In 2020, the average distributed wind project (excluding small-scale wind <100kW) had two turbines of size 2.2MW for a total plant size 4.4 MW [1].

Considering urban environments, the following distributed wind **cases** showcase possible applications:

1. **Small cluster of utility-scale wind turbines serving a local energy community** by providing energy to the local grid-connected microgrid. For example, the Konkanmäki wind farm (three x 3.45 MW wind turbines), built about 6km from Varkaus, with population 20 000 inhabitants [2] in Finland.
2. **Small cluster of utility-scale wind turbines co-located with a single isolated loads such as municipal infrastructure** (e.g. wastewater treatment plant, municipal solid waste plant, school), manufacturing plant, or retail space. For example, the Field Point Wastewater Treatment Facility, where the wind (3 x 1.5MW wind turbines) produces 45% of the plant needs [3]. A challenge is the combined requirement of wind resource availability and the suitability of the site for co-location with infrastructure.
3. **Wind power plant coupled with hydrogen electrolyser**, where both products hydrogen and oxygen are used. Hydrogen may be used to power urban transport or nearby hydrogen ferry in coastal locations, and oxygen may be used for purification in a nearby wastewater treatment plant. The 400kW hydrogen electrolyzer is fed by a 3MW wind turbine in the Brande pilot, producing enough hydrogen to fuel 50-70 cars every day [4]. A future system may include the

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Distributed wind

integration of an upscaled system with a nearby wastewater treatment plant for use of oxygen sub product. Potential upscaling to ~12MW wind and co-location with the harbour to feed hydrogen ferry [5].

The comparison between financial metrics of three wind energy installations is provided below (an exchange rate of 1.142USD/EUR has been used corresponding to 2020). The larger onshore turbine is of course more profitable. Further, wind farm projects closer to cities will have higher OPEX cost due to higher land lease prices.

	Project based on 2.8MW Land-Based wind turbine	Commercial Distributed Wind using 100kW wind turbine	Residential Distributed Wind using 20kW wind turbine
LCOE [EUR/MWh]	30	87	132
CapEx [EUR/kW]	1280	3765	4969
OpEx [EUR/kW/year]	38	31	31
Net capacity factor %	42.30%	32.50%	29.50%

(ref: Stehly, Tyler and Patrick Duffy. 2021. 2020 Cost of Wind Energy Review. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5000-81209)

CO-BENEFITS

Case 1:

- wind energy contributes to energy mix for climate change mitigation (clean affordable & secure energy),
- further distributed wind contributes to economy (operation and maintenance jobs: Increase employment rate and Jobs).
- distributed energy generation contributes to societal resilience, and specifically enhanced stability of urban infrastructure.

Case 2: in addition to co-benefits from case 1
* better waste efficiency (better waste management).

Case 3: similar co-benefit categories as in cases 1 and 2 but even more impact due to direct use of green electricity for green H2 production locally.

EXTERNAL LINKS

- (1) Orrel et al, "Distributed wind market report 2021" PNNL-31729.
- (2) https://ilmatar.fi/projekti/tetrituuli-fi/
- (3) https://www.tpomag.com/editorial/2015/02/wind_turbines_from_goldwind_usa_help_the_fields_point_treatment_plant_save
- (4) https://www.youtube.com/watch?v=6qM6poUc_qA, https://www.siemensgamesa.com/en-int/newsroom/2021/11/211110-siemens-gamesa-green-hydrogen-to-vehicles
- (5) Taia Kronborg (Lhyfe), presentation during Power2AX webinar on green Hydrogen utilization on Åland, 2021. https://flexens.com/pivoting-green-hydrogen-solutions-on-aland

Distributed wind

PRE-CONDITIONS & ENABLING CONDITIONS

Considering the case 3 presented:

Political:
Continued political support towards the project (time scale of wind farm projects can take five or more years), from awareness of project benefit to the municipality. Project well integrated in municipality urban planning.

Economic:
Support scheme for pilot facilities.

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Distributed wind	
	Social: High level of social acceptance of wind energy. The project clearly benefits the community. ***Technical:*** High wind resource near suitable greenfield for hydrogen plant and near a wastewater treatment plant. Consortium of companies experienced in wind, hydrogen, and municipal infrastructure. ***Legal:*** Favourable legal framework.
CONSTRAINTS/ BARRIERS for implementation	Considering case 3 presented above: ***Political:*** Veto from municipal government in the time scale required to develop the project, which may extend more than one electoral term. ***Economic:*** Risk premium for non-standard projects. Stakeholder requirements that limit wind turbine height, or force noise/flicker curtailment affect the performance of the wind power plant. ***Social:*** Community resistance to wind deployment (NIMBY). ***Technical:*** Wind resource availability, ice fall/ice throw in wind turbines close to industrial plant / dwellings. ***Legal :*** Legal framework uncertainty.
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	***Regarding case 1:*** In Finland, small wind power plants are relatively frequent: Considering operational wind farms as of 2021, 17% of wind power capacity was in plants of size < 20MW (average size 2.12MW), and 8% in plants of size less than 10MW (average size 1.86MW). Smaller wind power plants with smaller footprints are more easily integrated near cities or suburban areas. ***Regarding case 2:*** Requirements from stakeholders need to be well considered in advance during preliminary suitability analysis, as it may affect the efficiency of the wind plant. In case 2, the final wind turbine size (tip height) was reduced due to objection from Federal Aviation Administration, which resulted in reduced turbines with a relatively low capacity factor of 0.18. Source case 1: Finnish wind Power association, Wind power projects in Finland 2021: operating and dismantled wind turbines. Source case 2: Treatment Plant operator, Wind Turbines From Goldwind USA Help The Field's Point Treatment Plant Save $1 Million A Year
IMPACTS (Indicators & DNSH)	New wind power plants reduce CO_2 emissions if they replace the fossil fuel-based power generation. Regarding the impacts to place the wind turbines ***close to the cities***: The effect of co-location of wind power plants and loads reduces the losses in the transmission network. In Finland, transmission losses declared by Finnish Transmission System Operator Fingrid were on average 211 000 tonnes of CO_2 equivalent in 2017-2019 (2020, Fingrid's climate reporting in 2020). This represents approximately 0.4% of Finland's greenhouse gas emissions (2020, Fingrid main grid development plan 2019-2030). Further, wind power accounts in

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Distributed wind	
	Finland for a 10% share of electricity consumption (2021, Statistics Finland). Therefore, a rough estimate of grid transmission losses due to wind power plants is 21 100 tonnes CO_2 or 0.04% of Finland Greenhouse gas emissions. Co-location of a large share of wind power plants closer to electric loads such as those mentioned in cases 1, 2, and 3 above will contribute to reducing Greenhouse gas emissions. However, this increase in efficiency may be cancelled by the reduced wind farm capacity factor as a result of curtailments due to operations near the urban environment. The benefit of co-location should be analysed case by case.
Additional information from CASE STUDIES	• Orrel et al, "Distributed wind market report 2021" PNNL-31729. • Treatment Plant operator, Wind Turbines From Goldwind USA Help The Field's Point Treatment Plant Save $1 Million A Year • https://www.youtube.com/watch?v=6qM6poUc_qA • Green Hydrogen to vehicles, Siemens, 2021. • Taia Kronborg (Lhyfe), presentation during Power2AX webinar on green Hydrogen utilization on Åland, 2021.

3.2.2 Micro-hydropower generation in urban water networks

- Authors: **CARTIF**
- Knowledge Repository link: **https://netzerocities.app/resource-778**

Micro-hydropower generation in urban water networks

Cities are a framework where the **water-energy nexus** is becoming critical due to demographic movements, economic growth, or the inexorable increase in the demand for both resources. Metropolises around the world are also facing global change pressures due to climate change and water scarcity, which are making it a challenge to continue to deliver core urban water services without increasing the impact on the natural environment. Urban water networks can be considered a source of renewable energy as they usually hold untapped energy deriving from abundant pressure (water head) or kinetic energy (water flow). The sites with excess energy are located in existing storage/service reservoirs, wastewater systems (collection or discharge stages), or in devices already installed to alleviate the excess energy as pressure reducing values or Break pressure tanks. Micro-hydropower plants can be installed for generating "green electricity" using specially designed in-pipe turbines. Among the different available machines, Pump as Turbines are becoming the technological solution for micro-hydraulic projects. When more head (pressure) is available (i.e. there is a waterfall, even if it is small), other technologies such as Kaplan, Francis, or Pelton turbines can be used. Urban planners and water utilities must consider energy implications in decision-making on water systems and can consider this type of solution when defining or updating urban water strategies. The EU-funded LIFE NEXUS Project is mapping the energy recovery locations in European cities and has found that the potential hydropower capacity in more than 70 sites across Europe is about 3,000 MW.

Case studies can be found in a river, Grobweil, or in water networks (using pump-as-a turbine), Dwr Uisce.

Very low head [m]   More head and flow

PaT (Pump as a turbine)

Depending on the head and flow range, Kaplan, Francis, Pelton and other most common technologies are applicable.

Product life cycle stages & Modules (EN15978): D Energy recovery.

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Micro-hydropower generation in urban water networks	
KEYWORDS	It is related to: • Supporting municipalities to monitor resource flows in line with impact targets and measurement processes • Capacity building and engagement with municipalities to identify and co-create circular solutions and roadmaps • Capacity building for city officials to understand urban metabolisms and circular solution opportunities
EXTERNAL LINKS	• PaT: https://powerturbines.eu/wp-content/uploads/2020/08/20200108_Redawn_Project_France.pdf • Other: https://www.global-hydro.eu/fileadmin/user_upload/referenzen/kaplan/hausmening/Hausmening_Referenzblatt.pdf • Project: https://www.lifenexus.eu

Micro-hydropower generation in urban water networks	
PRE-CONDITIONS & ENABLING CONDITIONS	***Urban form and layout:*** All cities use pressured piping grids systems to supply water, while drain and sewage systems are usually gravity fed. Micro-hydropower plants are becoming particularly interesting for the integration of renewable resources because of the potential to harvest clean energy from excess head pressure or kinetic energy (water flow) [1]. Energy recovery can only be implemented if sites with excess of energy exists in the urban water network. Theoretically, all pressure reducing values or break pressure tanks could be replaced with in pipe generators, maintaining the same control on water flow and pressure whilst producing usable electricity (green electricity). It is important to mention that recovering energy at these locations will have no impact on the flow or pressure to downstream consumers. Furthermore, the pressure reduction is correlated to a decrease in the water leakages [2]. ***Technical aspects / infrastructure:*** Energy recovery in urban water networks can be carried out with traditional turbines or adapted machines [3]. When selecting the type of machine, it is necessary to consider the conditions of the specific location, such as water flow variability or the installed capacity potential. Pump as Turbines (PaT), a type of adapted machine, are the technological solution for micro-hydraulic projects (≤ 100 kW) [4]. The main advantages of PaTs compared with conventional machines are their large operating range, simple management and operation or lower cost and payback periods. The main negative aspects of PaTs are related to their low efficiency when operating outside their best efficiency point. Operation with different flows can be solved by the development of good regulation techniques. Issues related to the use of the generated energy for self-consumption may include storage in batteries and integrating this renewable energy in a similar manner as other supplementary sources (e.g., solar and wind). ***Policy and regulatory framework*** Apart from the technical aspects, it is necessary to evaluate the economic feasibility of the new hydropower projects and to consider the regulatory and policy context of each country as Feed-in-Tariffs, a policy mechanism based on price certainty and long-term contracts to renewable energy producers.
CONSTRAINTS/ BARRIERS for implementation	***Funding and financing:*** The current increase in the cost of turbines is affecting the profitability of the micro-hydropower plants (especially for those with a capacity potential). ***Regulatory/legal:***

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Micro-hydropower generation in urban water networks	
	Administrative obstacles to legalize facilities. In projects where an environmental license is required and includes the approval of the correspondent River Basin Authority, the process can take too long.
INSTRUMENTS/ Processes for implementation	***Educational, Capacity Building instruments:*** Capacity building and training: https://netzerocities.app/resource-1578 ***Planning instruments:*** Integrated climate plans for cities (i.e.: SECAPs): https://netzerocities.app/resource-1698 City water resilience assessment: https://netzerocities.app/resource-1738 ***Technical instruments:*** Urban metabolism mapping: https://netzerocities.app/resource-1893
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	Municipalities or local supply water companies execute turbine installation projects through **tendering process**. The cost the projects at the initial stage of launching the tender may become obsolete once it is awarded after a few months due to the global crisis and instability effect on the equipment prices. This may lead to tender companies refraining from participating in the processes or resign in case they are finally awarded. Very **long delivery periods** of the turbines (around 6 months). This can lengthen the duration of the construction works.
IMPACTS (Indicators & DNSH)	***Energy:*** Power capacity: 15 - 100 kW Energy generation: 60 - 400 MWh/year ***Economic:*** Capital estimation: 8,000-9,000 €/kW Payback time: less than 10 years
	DNHS: ***Climate change mitigation:*** This activity leads to a significant greenhouse gas emission reduction on a lifecycle basis. ***Sustainable use and protection of water and marine resources:*** The installation of a hydropower plant will produce a reduction of the pressure, which is correlated to a decrease in the water leakages. ***Circular economy:*** Efficient use of water in the urban water cycle.
Additional information from CASE STUDIES	Porma Drinking Water Treatment Plant (DWTP) in Valdefresno municipality in Leon, Spain (LIFE NEXUS Project). **Innovative** integration of a **Pump as Turbine** (PaT) coupled to a **battery storage**. The new prototype of 35 kW will recover the energy currently dissipated by a Pressure Reducing Valve (PRV) located at the entrance of the DWTP.

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Micro-hydropower generation in urban water networks

Indicators for the installation in Porma DWTP

Energy:
Power capacity: 45 kW
RES generation: 252 MWh/year
Share of energy supply coming from renewables: 100%
Emissions:
GHG emissions reduction according to previous energy generation: 100% reduction of CO_{2e}
Economic:
Cost savings: 36,600 €/year
Total cost of the system, along its lifetime: 373,000 €
Payback time: 9 years

Other PaT pilot installations in Murcia (Spain) [5] and Kildare (Ireland) [6]

References:

[1] Casini. M. (2015). Harvesting energy from in-pipe hydro systems at urban and building scale. ‖ International Journal of Smart Grid and Clean Energy. vol. 4, no. 4, pp 316-327.
[2] Almandoz, J.; Cabrera, E.; Arregui, F.; Cobacho, R. Leakage. (2005) Assessment through Water Distribution Network Simulation. J. Water Resour. Plan. Manag. 131, 458–466.
[3] Pérez-Sánchez M., Sánchez-Romero F.J., Ramos H.M., López-Jiménez A.L. (2017). Energy Recovery in Existing Water Networks: Towards Greater Sustainability. Water, 9 (97), 1-20.
[4] Hennig, T.;Wang, W.; Feng, Y.; Ou, X.; He, D. (2013). Review of Yunnan's hydropower development. Comparing small and large hydropower projects regarding their environmental implications and socio-economic consequences. Renew. Sustain. Energy Rev., 27, 585–595.
[5] Imbernón, J.A.; Usquin, B. (2014). Sistemas de generación hidráulica. Una nueva forma de entender la energía. In Proceedings of the II Congreso Smart Grid, Madrid, Spain, 27–28 October. (In Spanish)
[6] McNabola, A.; Coughlan, P.; Williams, A.P. (2014). Energy recovery in the water industry: An assessment of the potential of micro hydropower. Water Environ. J., 28, 294–304.

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3.2.3 Geothermal energy

- Authors: **REGEA**
- Knowledge Repository link: https://netzerocities.app/resource-788

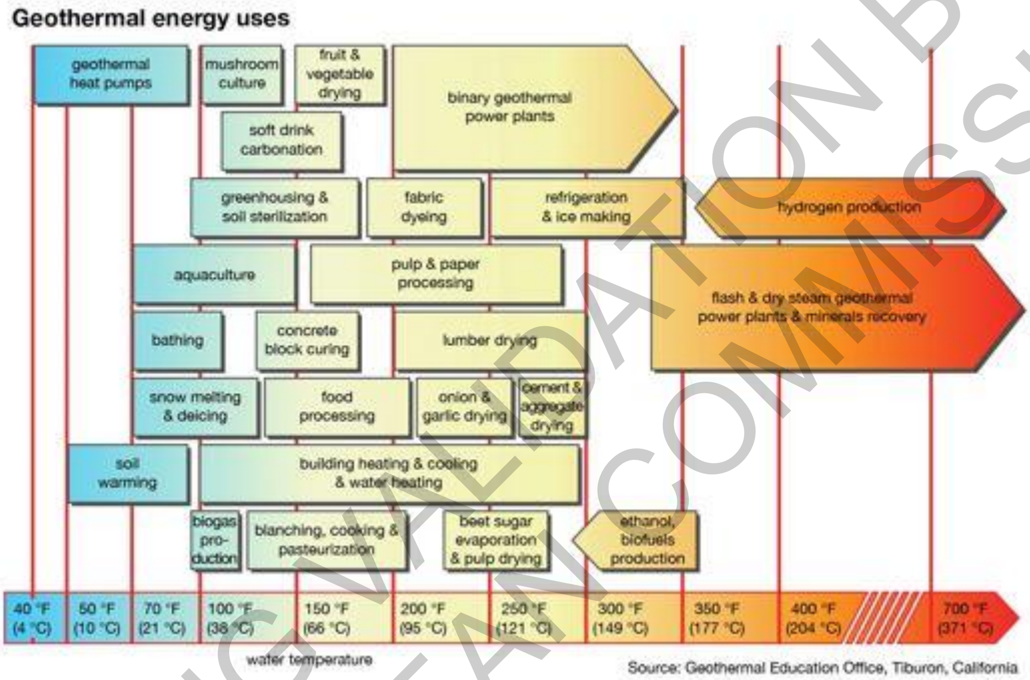
Geothermal energy
Geothermal energy has a long tradition in human history, from thermal baths to heating and power generation. It represents an important resource of renewable energy.

Geothermal energy

The use of geothermal energy normally requires **high temperatures** to be viable. This often means deeper and more expensive drilling work. Some **technologies** can produce power at lower temperatures but they are more expensive and usually less efficient resulting in a higher production cost.

The **drilling works** represent the majority of the costs of these systems so the depth at which energy sources are available will have a significant impact on the viability of the exploitation of geothermal energy.

Geothermal energy has a strong potential to be used in a cascading way from **power generation** at high temperatures to **heating**, **healthcare**, **pools** and **greenhouses** as the temperatures are reduced. Due to the higher temperatures needed for power generation, cascading use of energy is especially relevant in these cases.



Geothermal energy uses. Source: Britannica, Geothermal energy (https://www.britannica.com/science/geothermal-energy)

Recommendations for implementation of geothermal energy:

- Raising awareness about geothermal energy - resources, potential, possibilities of use, and economic aspects of geothermal projects
- Informing the public about geothermal energy exploitation with the aim of reaching a specific audience (engineers, architects, installers) of individual buildings and heating systems
- Initiation of works on the identification of new resources through assessment and characterization using geological and geophysical methods taken from the oil industry
- Search for technical and technological solutions for environmental protection during the process of production and consumption of geothermal and other waters
- Construction of the geothermal energy facility

CO-BENEFITS	The use of geothermal energy for heat production can greatly **reduce GHG emissions**, **increase technological readiness** locally and regionally, and **increase access to clean, affordable, and secure energy**.
EXAMPLES	• Mapping the resource in GIS, Krakow GeoPLASMA-CE (Interreg)

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Geothermal energy	
PRE-CONDITIONS & ENABLING CONDITIONS	***Climate and geography:*** So far, geothermal energy has been limited to areas where conditions allow the transfer of energy using water in liquid or gaseous form. Water transfers heat from deep hot zones to the surface, or at least near the surface, allowing humans to use it. The Earth's crust is permeable to liquids, rainwater, and other surface water penetrates in depth and exchanges heat with stones. Two primary heat exchange forms occur within the crust: conduction and convection. The resulting convective heat transfer is highly efficient in places where the rocks are vastly fractured, and circulating waters are abundant**. It can be easily exploited by drilling wells and releasing hot fluids to the surface. In rare cases, the liquid has such a high temperature that steam is formed depending on the pressure. Geothermal systems are created in areas that meet the conditions.** Geothermal systems can be located in regions with an average or above-average geothermal gradient, especially in regions around the edges of lithospheric plates where geothermal gradients can be significantly higher than the average value. Such a system consists of **3 main elements: a heat source, a reservoir and a liquid.** **The heat source** can be a high-temperature magmatic intrusion that has reached shallow depths (5-10 km) or the Earth's average temperature, which increases with depth. **A reservoir** is an accumulation of hot permeable rocks from which the circulating liquid (water) extracts heat—**the only element of the geothermal system that should be a natural heat source**. If conditions are favourable, the other two elements can be artificially constructed. After use, **the liquid** extracted from the reservoir for driving the turbines in the geothermal power plant can be returned below the surface through special injection wells. The system's impact on the environment is significantly reduced by injecting the used liquid back under the surface. Policy and regulatory/legal framework: Tax benefits in Hungary and France; Loans in Germany, Lithuania (theoretically) and Slovenia; Direct subsidies in Belgium, Germany (limited), Lithuania and Slovenia; Various forms of indirect support in most countries; Guaranteed incentive prices (still only for electricity): • Germany: 8-15 €-ct/kWh • Hungary: 12-14 €-ct/kWh • Slovenia: 5.86 €-ct/kWh • Austria: 7 €-ct/kWh Green certificates in Hungary and Romania; Carbon credits in Romania (first positive experiences in geothermal energy with Denmark as a partner, 5 €/t of reduced CO2), Germany, Poland (they exist, but do not yet have an impact on geothermal energy); Geothermal risk coverage, which is crucial for private investors., From the support measures mentioned above, 3 successful measures stand out, namely: • Loans/subsidies for installation; • Incentive prices (in accordance with relevant regulations); • Carbon credits. ***Funding and financing***: Horizon Europe, NER 300 programme: Funding for innovative low-carbon technology research with focus on environmentally safe Carbon Capture and Storage and innovative renewable energy technologies, European Climate Infrastructure and Environment Executive Agency (CINEA), European structural and investment funds (ESIF), LIFE, Prize for renewable energy

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Geothermal energy	
	islands, Horizon 2020 dashboard : Access to real-time programme data with the ability to filter by country, region, theme and more.
CONSTRAINTS/ BARRIERS for implementation	Geothermal energy has an enormous potential both for small-scale projects like home heating and for greenhouse or large district heating projects with subsoil thermal energy accumulation capable of supplying thermal energy to an entire city [1]. Unfortunately, market parameters, such as **acceptance from investors, regulatory framework, planning restrictions, and environmental impact**, need to be addressed for this kind of technology to achieve effective development. When discriminating renewable energies by type and thus separating geothermal from the rest and even its thermal or electrical end uses, economic barriers to low-enthalpy geothermal energy exist. On a global scale, the main barriers to the introduction of electrical uses for geothermal energy are economic/financial, while for thermal uses, they are cultural or social. At a regional level, in the EU economic/financial barriers are still the most important, both for low and high-enthalpy geothermal. [1] Borge-Diez, D.; et al, Geothermal source heat pumps under energy services companies finance scheme to increase energy efficiency and production in stockbreeding facilities. Energy 2015, 88, 821–836. [CrossRef]
INSTRUMENTS/ Processes for implementation	Some studies show the importance of land management (planning, agriculture, conservation) and geographic studies to implement energy strategies. Geothermal energy can be put into a myriad of uses and many have already been studied, though most of them are still in pilot stage—from electricity production to urban heating or agricultural applications, such as greenhouse and stockbreeding facilities heating, besides industrial applications through the use of underground infrastructures, heating for residential and official buildings and swimming pools, just to name a few. • Local energy communities: https://netzerocities.app/resource-618 • Loans for Energy Efficiency (EE): https://netzerocities.app/resource-1648 • Blended finance for Energy Efficiency (EE): https://netzerocities.app/resource-1658 • Integrated land use and urban planning with energy and climate: https://netzerocities.app/resource-1678
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	***1. Environmental Concerns about Greenhouse Emissions*** Unfortunately, no matter its reputation of being an environmentally friendly alternative energy source, geothermal energy also causes some minor concerns in regards to the environment. The extraction of geothermal energy from the grounds leads to a release of greenhouse gases like hydrogen sulfide, carbon dioxide, methane and ammonia. However, the amount of gas released is significantly lower than in the case of fossil fuels. ***2. Possibility of Depletion of Geothermal Sources*** Furthermore, despite being considered a sustainable and renewable energy, the chances are that specific locations might cool down after time, making it impossible to harvest more geothermal energy in future. The only non-depletable option is sourcing geothermal energy right from magma but the technology for doing so is still in the process of development. This option is worth the investment mainly thanks to the fact that magma will be around for billions of years. ***3. High Investment Costs for Geothermal System*** Another disadvantage is the high initial cost for individual households. The need for drilling and installing quite a complex system into one's home makes the price climb quite high. Nevertheless, the return on such investment is very promising, being able to earn the investment back within 2 to 10 years. ***4. Land Requirements for Geothermal System to Be Installed***

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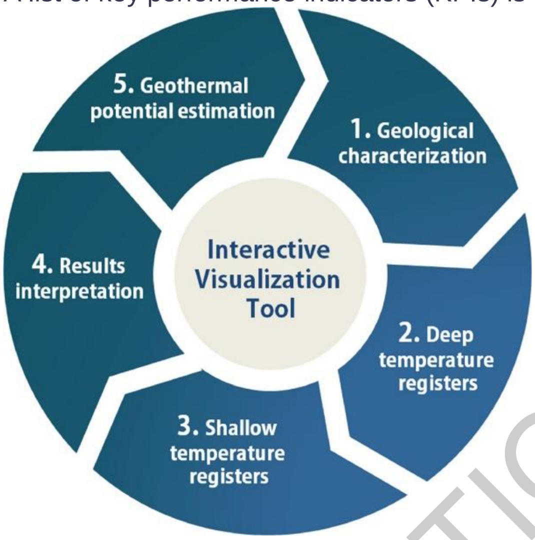
Geothermal energy	
	In case of geothermal systems, having a piece of land next to the house is required in order to be able to install one. That makes geothermal systems hard to be implemented for homeowners in big cities, unless a vertical ground source heat pump is used.
IMPACTS (Indicators & DNSH)	A list of key performance indicators (KPIs) is presented in Ref. [1] [2] [3] [4].  ***Energy indicators:*** • Primary energy savings • Useful energy demand (heating and cooling) • Final energy demand (fuel and electricity) • Seasonal COP of heat pumps • Share of energy supply coming from excess heat and renewables. • Renewable energy generation • Geothermal installed capacity ***Environmental indicators:*** • Greenhouse gases emissions • Greenhouse gases savings ***Economic indicators:*** • Cost savings • Total cost of the system, along its lifetime • CAPEX • OPEX • Payback time • Return of investment (RoI) • Internal rate of return (IRR) • Net present value (NPV) ***Social indicators:*** • People in favour of the project • Degree of people satisfaction • Average comfort perception • [1] J. Varney *et al.*,(2017) "Performance measures in geothermal power developements," Renewable Energy 101 (2017) pp 835-844 • [2] C.S. Bl´azquez *et al.* (2022) "Assessment of the geothermal potential in the region of ´Avila (Spain): An integrated and interactive thermal approach," Geothermics 98 (2022) 102294

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Geothermal energy	
	• [3] R. DiPippo (2012) "Geothermal Power Plants: Principles, Applications, Case Studies and Environmental Impact", Butterworth-Heinemann, 2012 [CrossRef] • [4] EIHP (2017) "Analiza sektora toplinarstva i iskorištavanja potencijala geotermalnih izvora na području Urbane aglomeracije Zagreb", GRAD ZAGREB, Gradski ured za strategijsko planiranje i razvoj Grada, 2017 [CrossRef]
	DNSH: ***Climate change mitigation*** This activity leads to a significant greenhouse gas emission reduction on a lifecycle basis ***Climate change adaptation*** By 2050, deployment of carbon-free geothermal energy can help address the climate change crisis by offsetting more than 500 million metric tons (MMT) of greenhouse gases in the electric sector and more than 1,250 MMT in the heating and cooling sectors. ***Circular economy*** In the power sector, geothermal deployment can grow to provide 60+ gigawatts-electric (GWe) of firm, flexible clean energy by 2050, with a major expansion of geothermal power production ***Pollution prevention and control*** Geothermal power plants emit 97% less acid rain-causing sulphur compounds and about 99% less carbon dioxide than fossil fuel power plants of similar size. **Geothermal power plants use scrubbers to remove the hydrogen sulphide naturally found in geothermal reservoirs.** This activity leads to a reduction of electricity consumption, and consequently to a reduction of emissions.
Additional information from CASE STUDIES	Sanyé-Mengual, E.; Romanos, H.; Molina, C.; Oliver, M.A.; Ruiz, N.; Pérez, M. Environmental and self-sufficiency assessment of the energy metabolism of tourist hubs on Mediterranean Islands: The case of Menorca (Spain). Energy Policy 2014, 65, 377–387. [CrossRef] Sibbitt, B.; McClenahan, D.; Djebbar, R.; Thornton, J.; Wong, B.; Carriere, J. The performance of a high solar fraction seasonal storage district heating system—Five years of operation. Energy Procedia 2012, 30, 856–865. [CrossRef] Energy 101: Geothermal Energy, U.S. Department of Energy, 2015.

3.2.4 Co-generation systems

- Authors: **REGEA**
- Knowledge Repository link:

Co-generation systems
Co-generation is the simultaneous production of **electricity and useful heat**. In a regular power plant, the heat remaining in the generation of electricity is released to the environment, mostly through cooling towers or cooling water, whereas in a cogeneration plant, the heat is recovered for use in homes, businesses, and industry.

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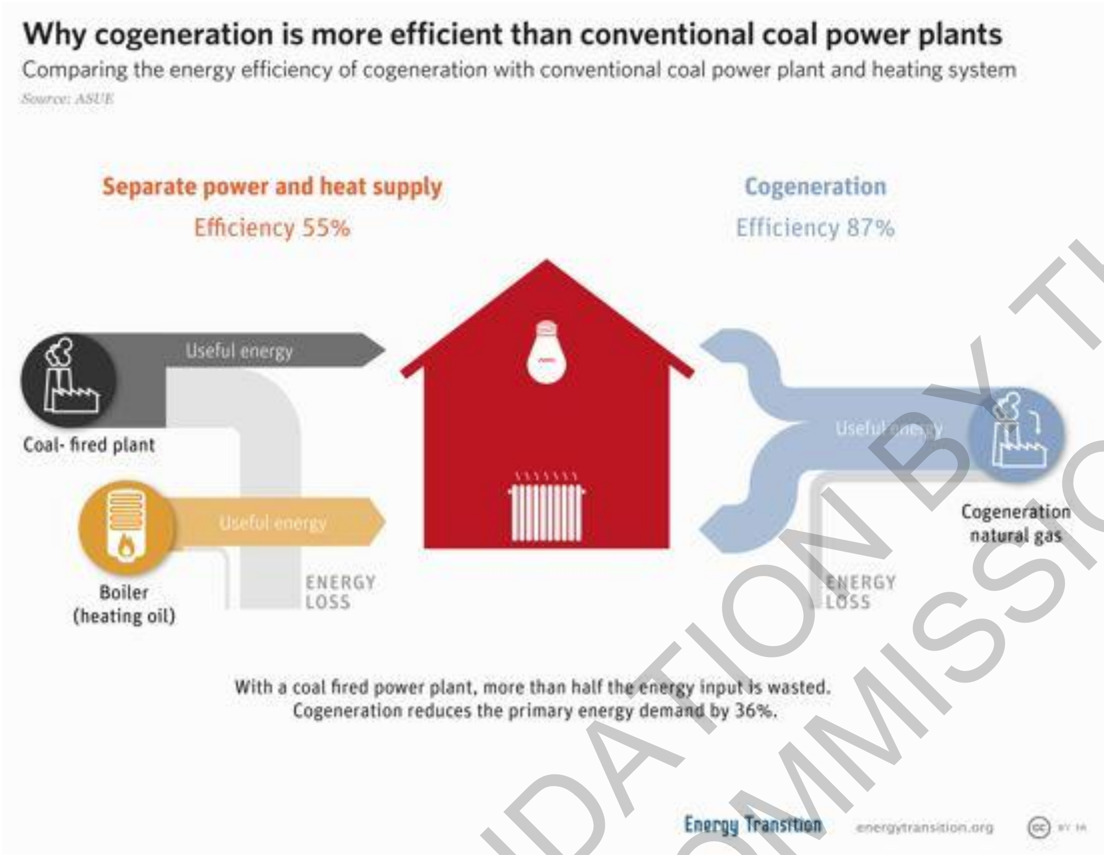
Co-generation systems	
 *Source: Energy transition - Cogeneration (https://wiki.energytransition.org/wiki/cogeneration/)* Such a system has **valuable properties** to **enhance the efficiency of fuel use**: the combined production of electricity and heat turns out to be more efficient than the separate production of these two forms of energy. Cogeneration plants can achieve energy efficiency levels of around 90%. All types of power plants can become cogeneration systems (e.g. steam power plants, gas turbines, combined cycle power plants, internal combustion engines) while the extracted heat largely varies in entity and temperature depending on technology, size, and operation parameters. The specific advantage of using steam turbines in comparison with the other prime movers is the option for using a wide variety of conventional as well as **alternative fuels** such as **biomass** or **hydrogen**. **Gas turbine** cogeneration has probably experienced the most rapid development in recent years due to the rapid progress in technology, a significant reduction in installation costs, and better environmental performance.	
CO-BENEFITS	Because of the higher efficiency of cogeneration systems, they **reduce GHG emissions** in comparison to the conventional technologies and therefore **improve air quality**.
EXTERNAL LINKS	• High-Efficiency Cogeneration Systems: The Case of the Paper Industry in Italy • Cogeneration: https://beeindia.gov.in/sites/default/files/2Ch7.pdf • An introduction to Power Plant Cogeneration (CED engineering) • Jämtkraft reveal plans for a new biomass CHP plant in Östersund (Bioenergy International) • Production of Sustainable Paper with cogeneration (COGEN World Coalition) • Cogeneration turbines help fire up sustainable paper production (Baker Hughes)

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<table>
<tr><th colspan="2">Co-generation systems</th></tr>
<tr><td>PRE-CONDITIONS & ENABLING CONDITIONS</td><td>Co-generation systems, also known as combined heat and power (CHP) systems, are highly efficient systems that generate both electricity and thermal energy from a single fuel source. The pre-conditions and enabling conditions for co-generation systems are as follows:

Climate and Geography:
The climatic conditions play an important role in the design and operation of co-generation systems. The case of the paper industry in Italy shows that the availability of biomass resources, such as forest residues and agricultural waste, is a key enabling condition for co-generation systems. The presence of natural assets, such as rivers, also plays a crucial role in the operation of hydroelectric power plants, which are a form of co-generation.

Urban Form and Layout:
The size and layout of cities can affect the design and operation of co-generation systems. Highly populated areas with high energy demands are ideal locations for co-generation systems. For example, highly-energy intensive industries within city boundaries, such as the paper industry, can benefit greatly from co-generation systems.

Technical Aspects/Infrastructure:
The existing city infrastructure and local R&I infrastructure play an important role in the deployment of co-generation systems. The availability of enabling digital and data infrastructures, such as ICT, IoT, big data analytics, and environmental monitoring, can help optimize the performance of co-generation systems. The availability of a reliable electricity grid infrastructure is also a key enabling condition. The case of Jämtkraft's biomass CHP plant in Östersund, Sweden, shows that usable surface areas for biomass storage and handling are important pre-conditions for biomass-based co-generation systems.

Policy and Regulatory/Legal Framework:
The policy and regulatory/legal framework can either enable or hinder the deployment of co-generation systems. Relevant EU/national laws, standards, and regulations should support the deployment of co-generation systems. Strategic alignment with regional/national objectives can also be an enabling condition. The availability of funding and financing options, such as the Just Transition Fund and the European City Facility (EUCF), can also be an enabling condition.

<u>Funding and Financing:</u>
Funding and financing are crucial enabling conditions for the deployment of co-generation systems. Fiscal decentralization and own resources, incentives, subsidies, availability of private capital, access to EU funding, and innovation procurement are all important funding and financing options. Blended finance for energy efficiency and loans for energy efficiency can also be used to fund co-generation projects.

Economic and Social Context:
The economic and social context can also affect the deployment of co-generation systems. Demographics, GDP per capita, cost of take-up, digital divide vs inclusion, citizen awareness, education, and digital skills are all important factors to consider.

Project Governance and Implementation Modalities:
The models of public services design and delivery, including engagement and participation of citizens and local private/public stakeholders, citizen-engagement and co-creation initiatives, stakeholder consultation, public-private partnerships, experimentation/testing needs, contracting of services including maintenance, and implementation by citizens/private companies are all crucial factors in the successful deployment of co-generation systems.</td></tr>
</table>

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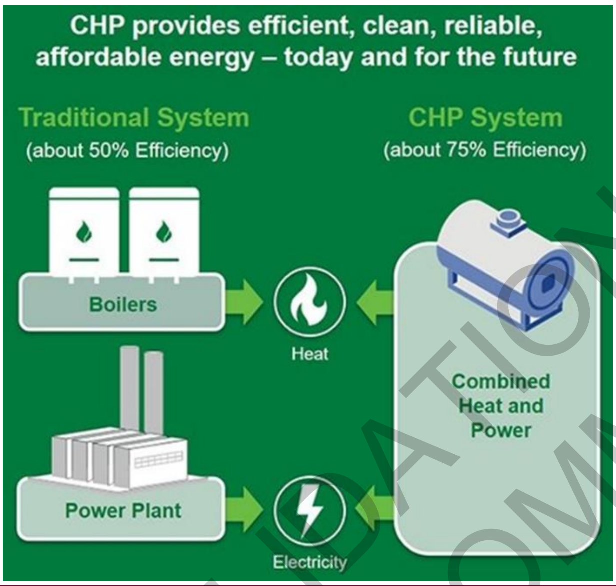
Co-generation systems	
	In conclusion, the deployment of co-generation systems requires a combination of pre-conditions and enabling conditions. The availability of natural assets, such as biomass resources and rivers, along with a reliable electricity grid infrastructure and usable surface areas for biomass storage and handling, are key pre-conditions. The policy and regulatory/legal framework should support the deployment of co-generation systems, and funding and financing options should be available. The economic and social context and project governance and implementation modalities should also be considered in the successful deployment of co-generation systems. 
CONSTRAINTS/ BARRIERS for implementation	***Climate and geography:*** High variability in climatic conditions, including fluctuations in temperature, humidity, and wind speed, can affect the efficiency of cogeneration systems. The availability and accessibility of natural resources, such as biomass and water, can be limited in certain geographic locations. ***Urban form and layout:*** The size and layout of urban areas can affect the availability of usable surface areas for the installation of cogeneration systems. Land use regulations and zoning laws may restrict the installation of cogeneration systems in certain areas. ***Technical aspects/infrastructure:*** Existing city infrastructure, including electricity grid infrastructure, may not be able to accommodate the increased demand for electricity and heat from cogeneration systems. The lack of interoperability and standards across different systems and technologies can create technical difficulties and limit the scalability of cogeneration systems. Highly energy-intensive industries within city boundaries can compete for resources and limit the availability of feedstocks for cogeneration systems. ***Policy and regulatory/legal framework:*** The absence of clear and consistent regulatory frameworks can create uncertainty and deter investors from financing cogeneration projects. Decentralization of state powers can create a lack of coordination and consistency in energy policy and regulation across different regions and municipalities. Data policies, including restrictions on data sharing and access, can limit the ability of stakeholders to collaborate and develop innovative solutions.

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Co-generation systems	
	Funding and financing: The availability of private capital for financing cogeneration projects can be limited due to high upfront costs and long payback periods. The lack of clear and consistent incentives and subsidies for cogeneration systems can create uncertainty and deter investors from financing these projects. The limited access to EU funding and innovation procurement can also limit the availability of funding for cogeneration projects. ***Economic and social context:*** The cost of take-up for cogeneration systems can be high in relation to GDP per capita, making it difficult for some households and businesses to adopt these systems. The digital divide and lack of digital skills and awareness can limit the ability of some stakeholders to participate in the development and implementation of cogeneration projects. ***Project governance and implementation modalities:*** The lack of engagement and participation of citizens and local private/public stakeholders can limit the knowledge and skills available for the development and implementation of cogeneration projects. The lack of coordination and collaboration among different stakeholders can create conflicts and delays in the implementation of cogeneration projects. The lack of experimentation and testing of different solutions can limit the ability of stakeholders to identify and implement the most effective and efficient cogeneration systems. Overall, overcoming these barriers will require a combination of policy and regulatory reforms, innovative financing mechanisms, technical solutions, and stakeholder engagement and collaboration. By addressing these barriers, it may be possible to unlock the full potential of cogeneration systems and achieve greater energy efficiency, cost savings, and environmental sustainability.
INSTRUMENTS/ Processes for implementation	***Funding and financing:*** Horizon Europe, NER 300 programme (Funding for innovative low-carbon technology research with focus on environmentally safe Carbon Capture and Storage and innovative renewable energy technologies), European Climate Infrastructure and Environment Executive Agency (CINEA), European structural and investment funds (ESIF), LIFE, Prize for renewable energy islands, Horizon 2020 dashboard (Access to real-time programme data with the ability to filter by country, region, theme and more).
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	***Pros:*** **Increased efficiency**: Cogeneration systems are more efficient than traditional power plants because they use the waste heat generated during electricity production to provide heating or cooling, which would otherwise be wasted. **Reduced energy costs**: Because cogeneration systems use waste heat, they can help reduce overall energy costs by reducing the amount of electricity and heat that needs to be purchased from external sources. **Improved environmental performance**: Cogeneration systems produce less greenhouse gas emissions than traditional power plants, which helps reduce environmental impact and can make them more attractive to environmentally conscious consumers. **Enhanced energy security**: Cogeneration systems can help improve energy security by providing on-site generation of electricity and heat, reducing reliance on external sources. **Versatility**: Cogeneration systems can be used in a variety of settings, including residential, commercial, and industrial applications. **Cons**: **High initial investment costs**: Cogeneration systems typically require a significant upfront investment, which may be a barrier to adoption for some organizations.

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Co-generation systems	
	Maintenance and repair costs: Cogeneration systems require ongoing maintenance and repair to ensure optimal performance, which can be costly. **Technical challenges**: Designing, installing, and operating cogeneration systems can be complex and may require specialized expertise. **Limited applicability**: Cogeneration systems may not be suitable for all applications or settings, as their efficiency is highly dependent on the specific use case. **Potential environmental impact**: While cogeneration systems can reduce greenhouse gas emissions, they may still have a negative environmental impact if not designed and operated properly. Overall, cogeneration systems have the potential to provide significant benefits in terms of energy efficiency, cost savings, and environmental performance. However, their implementation may be limited by the high initial investment costs, technical challenges, and maintenance requirements. Careful planning and ongoing attention to system design and operation are critical to realizing the full benefits of cogeneration systems while minimizing their potential drawbacks.
IMPACTS (Indicators & DNSH)	The values of co-generation systems for the indicators listed can vary depending on the specific system and its operating conditions. However, here are some approximate values: **Power absorption (kW):** This will depend on the size of the co-generation system and the amount of electricity it is designed to produce. For example, a small co-generation system designed to power a single home might have a power absorption of around 5 kW, while a larger system designed to power a commercial building could have a power absorption of several hundred kW. **Coefficient of Performance (COP):** The COP of a co-generation system will depend on the type of system and the operating conditions, but a typical value for a well-designed system is around 0.7 to 1.0. **Thermal efficiency (%):** Again, this will depend on the system, but a typical thermal efficiency for a co-generation system is around 80-90%. **Electrical efficiency (%):** The electrical efficiency of a co-generation system is typically in the range of 20-30%. **Fuel consumption (L/h):** The fuel consumption of a co-generation system will depend on the type of fuel used, the size of the system, and the operating conditions. For example, a small natural gas-fired co-generation system might have a fuel consumption of around 0.2-0.3 L/h, while a larger system powered by diesel might consume several litters of fuel per hour. **Total heat generated (kW):** The total heat generated by a co-generation system will depend on the size of the system and the operating conditions, but a typical value might be in the range of 80-90% of the system's total output. So, for example, a 100 kW co-generation system might generate around 80-90 kW of heat.
	Benefits from achieved indicators: • Emissions of GHG from the production and processing of energy per unit of energy output (tons CO2e/MWh or tons CO2e/MJ or CO2e/m2) • GHG emissions reduction (e.g., by replacing an energy-hungry system with the solution in object) per unit of energy output (tons CO2e/MWh or tons CO2e/MJ or CO2e/m2) • GHG emissions avoidance (e.g., by removing the need for energy consumption or by reducing the trip length) (%CO2e) • Energy consumption per unit of end-use activity (kWh/m2/y) • Energy savings compared to reference building (% kWh/m2/y)

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Co-generation systems	
	• Total capital requirements per unit of energy output or installed capacity (EUR/MW or EUR/MJ) • Total capital requirements per unit of output (EUR/unit) • Total annual operational costs per unit of energy output (EUR/MWh or EUR/MJ) • Total annual operational costs per unit or per energy output (EUR/unit or EUR/MJ) • It is important to note that the impact of co-generation systems can be difficult to quantify as it is often context-specific and depends on a number of other factors. Therefore, it is recommended to provide a range of values or a narrative of the expected impact if a quantification is not possible. In addition, the DNSH principle should be considered to ensure that the co-generation systems do not cause significant harm to the environment. For instance, any activity that leads to significant greenhouse gas emissions on a lifecycle basis should be avoided.
Additional information from CASE STUDIES	Additional examples of co-generation systems from case studies: The University of British Columbia (UBC) in Vancouver, Canada has a co-generation system that produces 12 MW of electricity and 26 MW of thermal energy using natural gas as fuel. This system provides electricity and heat for the campus, reducing greenhouse gas emissions by 22,000 tonnes annually. The Burj Khalifa in Dubai, the tallest building in the world, has a co-generation system that uses waste heat from the air conditioning system to generate electricity and provide hot water. This system reduces the building's energy consumption by 15% and saves approximately 6,000 tonnes of carbon emissions annually. The Boston Medical Centre in Massachusetts, USA has a co-generation system that produces 2 MW of electricity and 4 MW of thermal energy using natural gas as fuel. This system provides electricity and heat for the hospital and its surrounding neighbourhood, reducing greenhouse gas emissions by 16,000 tonnes annually. The St. Olav's Hospital in Trondheim, Norway has a co-generation system that produces 7 MW of electricity and 16 MW of thermal energy using natural gas as fuel. This system provides electricity and heat for the hospital and the neighbouring university, reducing greenhouse gas emissions by 12,000 tonnes annually. Links to resources on co-generation systems from case studies: • Case Studies on Cogeneration Projects in Thailand: https://www.osti.gov/biblio/750437-case-studies-cogeneration-projects-thailand • Cogeneration Case Studies: Efficiency in Energy and Environment: https://www.bundesverband-kwk.de/fileadmin/media/downloads/BWK-Broschueren/2010_Cogeneration_Case_Studies.pdf • Case Study of Cogeneration System Installed in a Hospital: https://www.ijert.org/research/case-study-of-cogeneration-system-installed-in-a-hospital-IJERTV7IS110270.pdf • Cogeneration Case Studies in the Hospitality Industry: https://www.energy.gov/eere/amo/downloads/cogeneration-case-studies-hospitality-industry • Cogeneration case study - Sainsbury's Dartmouth: https://www.theade.co.uk/resources/cogeneration-case-study-sainsburys-dartmouth

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3.2.5 Sustainable biomass and biogas power

- Authors: **REGEA**
- Knowledge Repository link: https://netzerocities.app/resource-808

Sustainable biomass and biogas power

Biomass includes all **land- and water-based vegetation**, as well as **all organic wastes**. As a renewable energy source, biomass is used for facility heating, electric power generation, and combined heat and power (**CHP**). For the cities, the preferable way of the utilization of biomass for **electricity generation** is in CHP plants with supply to a district heating network since this is the most effective way to use biomass. CHP is typically consisting of a biomass-fired boiler whose steam is used to propel a steam turbine in addition to the extraction of steam or heat for process use. The benefit of using biomass for electricity generation is its ability to be stored, and thus it can easily be used for peak load generation.

Ways to release the energy stored in biomass include **pyrolysis**, **anaerobic digestion**, and **conversion to gas/liquid fuel**. Methods are selected depending on the types of biomass. Woody biomass is most often combusted or gasified to generate electricity. Biomass like wheat straw and very wet wastes are converted into gas in an anaerobic digester.

Biogas produced by anaerobic digestion is used to **produce electricity, heat or as a vehicle fuel**. In Europe, most the modern anaerobic digestors provide electricity and heat in electricity-only, heat-only, or Combined Heat and Power (CHP) plants. Biogas production can be used for self-production/consumption.

In high-income countries, biogas is used primarily in electricity-only and CHP plants. About 50% of total biogas consumption in Europe was used for heat production.

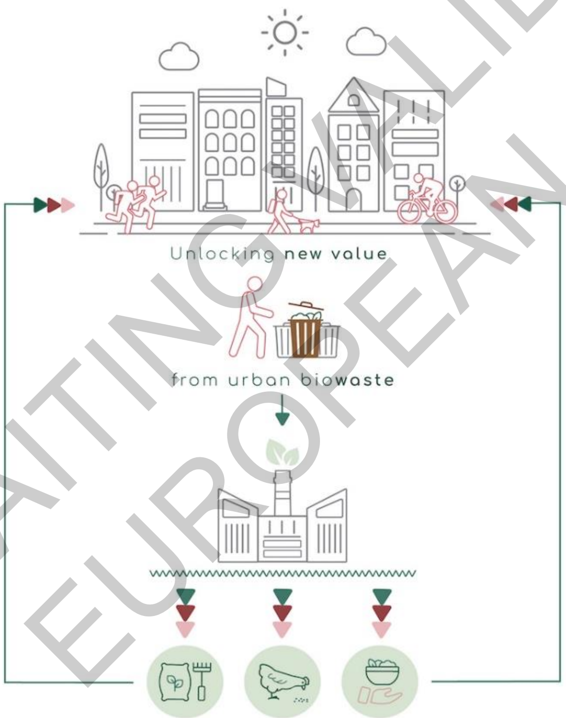

Figure: from EU project VALUE WASTE: https://valuewaste.eu/

CO-BENEFITS	Most of the studies show that the usage of biomass and biogas for energy generation can help to **reduce GHG emissions**. Due to the vast local availability of different types of biomass, its use can **increase access to clean, affordable, and secure energy.** Since waste materials can be converted to energy, the utilisation of biomass and biogas in energy production can achieve **better waste management and reduce food waste.**

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Sustainable biomass and biogas power	
EXTERNAL LINKS	• https://www.epa.gov/chp • Biomass for Electricity Generation | WBDG - Whole Building Design Guide • Nicolae Scarlat, Jean-François Dallemand, Fernando Fahl. Biogas: Developments and perspectives in Europe. Renewable Energy, Volume 129, Part A, 2018, Pages 457-472, https://doi.org/10.1016/j.renene.2018.03.006 • Isabel Malico, Ricardo Nepomuceno Pereira, Ana Cristina Gonçalves, Adélia M.O. Sousa. Current status and future perspectives for energy production from solid biomass in the European industry. Renewable and Sustainable Energy Reviews, Volume 112, 2019, Pages 960-977, https://energy.ec.europa.eu/topics/renewable-energy/bioenergy/biomass_en

Sustainable biomass and biogas power	
PRE-CONDITIONS & ENABLING CONDITIONS	Sustainable biomass and biogas power can play a crucial role in achieving renewable energy targets while reducing greenhouse gas emissions. Here is an overview of pre-conditions/minimum requirements and enabling conditions/ideal design environment for sustainable biomass and biogas power: ***Pre-conditions/minimum requirements:*** ***Climate and geography:*** Adequate biomass resources, such as forests, agricultural residues, and municipal waste, are necessary for biomass power generation. Additionally, favourable climatic conditions, such as consistent rainfall and moderate temperatures, are essential for the growth of biomass resources. Access to suitable land for the cultivation of energy crops, avoiding conflicts with food production and conservation areas. ***Technical aspects/infrastructure:*** Infrastructure such as transportation, storage, and conversion technologies are essential to maximize the potential of biomass resources for power generation. For biogas power, the minimum requirement is the presence of organic waste or biomass that can be converted into biogas. ***Policy and regulatory/legal framework:*** A clear regulatory and legal framework that defines the rules and standards for sustainable biomass and biogas power generation is necessary. The policies should encourage the use of sustainable biomass resources, and regulatory frameworks should ensure that biomass and biogas production does not harm the environment or compete with food production. ***Enabling conditions/ideal design environment:*** ***Climate and geography:*** Favourable climatic conditions and geography can create an ideal environment for the growth of biomass resources. For example, areas with high rainfall, good soil quality, and plenty of sunshine can support the growth of energy crops. ***Urban form and layout:*** A well-designed urban form and layout can facilitate the collection and transportation of biomass resources to power plants. For example, cities with efficient waste collection systems can provide a reliable source of organic waste for biogas production. ***Technical aspects/infrastructure:*** Advanced technologies for biomass conversion, such as gasification and pyrolysis, can improve the efficiency and sustainability of biomass power generation. Additionally, enabling digital and data infrastructures, such as environmental

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Sustainable biomass and biogas power	
	monitoring systems, can help optimize the use of biomass resources and reduce environmental impacts. **Policy and regulatory/legal framework:** Favourable policies and regulations, such as feed-in tariffs, tax incentives, and subsidies, can encourage the development of sustainable biomass and biogas power generation. Additionally, strategic alignment with regional/national objectives, decentralization of state powers/competences, and innovation procurement can support the implementation of sustainable biomass and biogas power generation. ***Funding and financing:*** Access to funding and financing sources, such as the Just Transition Fund, LIFE, and the European City Facility, can support the development and implementation of sustainable biomass and biogas power generation projects. Additionally, innovative financing models, such as blended finance and green bonds, can help mobilize private capital for sustainable biomass and biogas power generation projects. ***Economic and social context:*** The economic and social context, such as citizen awareness, education, and digital skills, can impact the adoption and implementation of sustainable biomass and biogas power generation. Additionally, citizen engagement, co-creation initiatives, and stakeholder consultation can foster social acceptance and participation in sustainable biomass and biogas power generation projects. ***Project governance and implementation modalities:*** Effective governance and implementation modalities, such as public-private partnerships, experimentation/testing needs, and contracting of services, can support the successful implementation of sustainable biomass and biogas power generation projects. Additionally, citizen participation, mobilization of collective knowledge and skills, and stakeholder consultation can facilitate the co-creation and implementation of sustainable biomass and biogas power generation projects. In conclusion, sustainable biomass and biogas power generation can play a crucial role in achieving renewable energy targets and reducing greenhouse gas emissions. However, it requires a clear regulatory and legal framework, favourable policies and regulations, advanced technologies, access to funding and financing, citizen participation, and effective governance and implementation modalities to realize its full potential. Additional sources: Key factors for the successful implementation of urban biowaste selective collection schemes https://www.cencenelec.eu/media/CEN-CENELEC/CWAs/RI/cwa17866_2022.pdf *Published first-of-its-kind European pre-standard CWA 17866 by the VALUEWASTE project*
CONSTRAINTS/ BARRIERS for implementation	***Climate and geography:*** ***Availability of biomass:*** The implementation of sustainable biomass and biogas power is dependent on the availability of biomass, which is affected by climate and geography. Regions with unfavourable climatic conditions may not have sufficient biomass to sustain the operation of the power plant. ***Natural disasters:*** Natural disasters such as floods, hurricanes, and earthquakes can damage the infrastructure required for the operation of the power plant, making it difficult to produce sustainable biomass and biogas power. ***Urban form and layout:*** ***Land use:***

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Sustainable biomass and biogas power	
	Land use issues, such as zoning laws, can impact the development of sustainable biomass and biogas power. For example, there may be zoning laws that prohibit the use of certain types of land for power generation purposes. ***Community acceptance:*** Community acceptance is crucial for the successful implementation of sustainable biomass and biogas power. However, there may be resistance from local communities due to concerns about air pollution, noise, and other environmental impacts. ***<u>Technical aspects/infrastructure:</u>*** ***Access to technology:*** The implementation of sustainable biomass and biogas power requires access to appropriate technology, which may not be available in all regions. ***Infrastructure:*** Adequate infrastructure, including transportation, storage, and distribution systems, is necessary for the successful implementation of sustainable biomass and biogas power. ***<u>Policy and regulatory/legal framework:</u>*** ***Inconsistent regulations:*** Inconsistent or conflicting regulations at the local, regional, and national levels can hinder the implementation of sustainable biomass and biogas power. ***Lack of policy support:*** A lack of policy support, such as incentives and subsidies, can make it difficult to attract investment in sustainable biomass and biogas power. ***<u>Funding and financing:</u>*** ***High upfront costs:*** The upfront costs of implementing sustainable biomass and biogas power can be high, making it difficult for investors to justify the investment. ***Access to financing:*** Access to financing can be a challenge for smaller-scale projects, which may struggle to secure funding from traditional sources such as banks. ***<u>Economic and social context:</u>*** ***Competing priorities:*** Economic and social priorities, such as job creation and economic development, may compete with the implementation of sustainable biomass and biogas power. ***Education and awareness:*** Education and awareness about the benefits of sustainable biomass and biogas power may be limited, making it difficult to build public support for the implementation of these projects. ***<u>Project governance and implementation modalities:</u>*** ***Lack of coordination:*** Lack of coordination among stakeholders, including local governments, community groups, and investors, can hinder the successful implementation of sustainable biomass and biogas power projects. ***Capacity building:*** Capacity building is necessary to ensure that the necessary skills and expertise are available to successfully implement and operate sustainable biomass and biogas power projects. Overall, the successful implementation of sustainable biomass and biogas power requires careful consideration of a range of factors, including technical feasibility, regulatory frameworks, financing mechanisms, and social acceptance. Addressing the potential barriers outlined above will be critical to the successful implementation of these projects, and policymakers and stakeholders must work together to address these challenges.

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<table>
<tr><th colspan="2">Sustainable biomass and biogas power</th></tr>
<tr><td>INSTRUMENTS/ Processes for implementation</td><td>Funding and financing:
Horizon Europe, NER 300 programme
(Funding for innovative low-carbon technology research with focus on environmentally safe Carbon Capture and Storage and innovative renewable energy technologies), European Climate Infrastructure and Environment Executive Agency (CINEA), European structural and investment funds (ESIF), LIFE, Prize for renewable energy islands, Horizon 2020 dashboard (Access to real-time programme data with the ability to filter by country, region, theme and more)

The following instruments could be most relevant for promoting sustainable biomass and biogas power:

Educational, Capacity Building instruments:
• User Engagement for Energy Performance Improvement - https://netzerocities.app/resource-1498
• Local energy communities - https://netzerocities.app/resource-618
• Capacity building and engagement with municipalities to identify and co-create circular solutions and roadmaps - https://netzerocities.app/resource-1548
• Capacity building for city officials to understand urban metabolisms and circular solution opportunities - https://netzerocities.app/resource-1568
• Capacity building and training - https://netzerocities.app/resource-1578
• Educational/Capacity building barriers identification - https://netzerocities.app/resource-1588

Involving, Collaborating and Empowering instruments:
• Urban-scale environmental decision support system (DSS) based on EPC (Energy Performance Certificate) databases - https://netzerocities.app/resource-1598

Financial instruments:
• Loans for Energy Efficiency (EE) - https://netzerocities.app/resource-1648
• Blended finance for Energy Efficiency (EE) - https://netzerocities.app/resource-1658

Planning instruments:
• Integrated land use and urban planning with energy and climate: https://netzerocities.app/resource-1678
• Integrated climate plans for cities (i.e.: SECAPs): https://netzerocities.app/resource-1698</td></tr>
<tr><td>DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation</td><td>Sustainable biomass and biogas power are renewable energy sources that have gained popularity in recent years due to their potential to reduce greenhouse gas emissions and contribute to energy security. However, their implementation is not without challenges and drawbacks.

Possible Drawbacks:
Land Use Change: One of the main drawbacks of sustainable biomass and biogas power is land use change. In some cases, large areas of land are required to grow the crops used for biomass and biogas production. This can lead to deforestation and land use change, which can have negative impacts on biodiversity and ecosystem services.
Feedstock Availability: Sustainable biomass and biogas power is heavily reliant on the availability of biomass feedstock, which can be affected by factors such as weather, pests, and disease. This can lead to fluctuations in biomass prices and supply, making it difficult for businesses to plan and invest in this sector.
Transportation and Logistics: The transportation and logistics of biomass feedstocks can be challenging, especially for areas that are located far from biomass production sites. The transportation of biomass feedstocks can also</td></tr>
</table>

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Sustainable biomass and biogas power	
	contribute to greenhouse gas emissions, offsetting the environmental benefits of using renewable energy sources. **Technical Challenges**: There are technical challenges associated with the conversion of biomass and biogas into usable energy. The conversion process can be complex and requires advanced technologies and equipment that can be expensive and require specialized knowledge and training. ***Possible advantages:*** **Reduced Greenhouse Gas Emissions**: Sustainable biomass and biogas power has the potential to reduce greenhouse gas emissions compared to fossil fuel-based energy sources, which can help mitigate climate change. **Energy Security**: Sustainable biomass and biogas power can contribute to energy security by reducing dependence on fossil fuels and increasing the use of locally produced renewable energy sources. **Job Creation**: The development of sustainable biomass and biogas power can create jobs in the agricultural and energy sectors, providing economic benefits to communities. **Economic Viability**: The economic viability of sustainable biomass and biogas power depends on various factors such as feedstock availability, technology costs, and government policies. The implementation of sustainable biomass and biogas power can be expensive initially, but long-term benefits can be significant. Overall, the implementation of sustainable biomass and biogas power has the potential to bring many benefits, but it also poses challenges and drawbacks that need to be addressed.
IMPACTS (Indicators & DNSH)	***Cost:*** The cost of producing energy from sustainable biomass and biogas depends on various factors such as the cost of feedstock, technology used, and the scale of the production. However, in general, sustainable biomass and biogas power are considered to be relatively cost-competitive compared to other renewable energy sources such as wind and solar power. According to the International Renewable Energy Agency (IRENA), the levelized cost of electricity (LCOE) for biomass power plants ranges from 0.05 to 0.17 USD/kWh, while the LCOE for biogas power plants ranges from 0.06 to 0.19 USD/kWh. ***Emissions:*** Sustainable biomass and biogas power can significantly reduce greenhouse gas emissions compared to fossil fuel-based energy sources. Biomass power plants emit carbon dioxide (CO_2) when they burn biomass, but this is considered to be carbon-neutral because the carbon released is offset by the carbon absorbed by the plants during their growth. However, emissions from biomass combustion can also include pollutants such as particulate matter, nitrogen oxides (NO_x), and sulphur dioxide (SO_2), which can have negative impacts on air quality and human health. Biogas power plants emit methane (CH_4) during the digestion process, but this is considered to be a much less potent greenhouse gas than CO_2, and any emissions can be captured and used for energy generation or offset by reducing emissions elsewhere. According to IRENA, the greenhouse gas emissions from biomass and biogas power plants can range from 16 to 270 g CO_2eq/kWh and 14 to 48 g CO_2eq/kWh, respectively. ***Energy consumption:*** The energy consumption associated with sustainable biomass and biogas power depends on the type of technology used and the efficiency of the production process.

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Sustainable biomass and biogas power	
	In general, biomass and biogas power plants require significant amounts of energy for the collection, transportation, and processing of feedstock, but this energy can be offset by the energy produced from the power plant itself. According to IRENA, the energy consumption for biomass power plants can range from 0.09 to 0.3 kWh/kWh, while the energy consumption for biogas power plants can range from 0.01 to 0.2 kWh/kWh.
	Energy Access: According to the International Energy Agency (IEA), around 1 billion people worldwide do not have access to electricity. To provide electricity access to these people, it would require an estimated 10-30 GW of additional capacity from sustainable biomass and biogas sources. ***Energy Security:*** The exact amount of sustainable biomass and biogas power needed to ensure energy security varies by country, but a good benchmark is to aim for at least 10-15% of total electricity generation to come from these sources. ***Climate Change Mitigation:*** According to the Intergovernmental Panel on Climate Change (IPCC), in order to limit global warming to 1.5°C above preindustrial levels, we need to rapidly transition to a net-zero emissions economy. This would require a significant increase in the use of sustainable biomass and biogas sources, with estimates ranging from 200-400 EJ per year by 2050. ***Air Pollution Reduction:*** Air pollution reduction can be achieved by replacing fossil fuels with sustainable biomass and biogas sources. For example, replacing coal-fired power plants with biogas plants can significantly reduce local air pollution levels. The exact amount of power needed to achieve significant air pollution reduction varies by location, but in general, replacing 20-30% of coal-fired power with sustainable biomass and biogas sources can make a noticeable difference. ***Economic Development:*** Sustainable biomass and biogas sources can be a valuable source of income for rural communities, especially in developing countries. The exact amount of power needed to support economic development varies depending on the specific community and the local energy demand, but in general, a few MW of additional capacity can have a significant impact on local economic growth.
Additional information from CASE STUDIES	Additional information from a few case studies on sustainable biomass and biogas power: • Case study on biomass power generation in Japan: This case study provides an overview of biomass power generation in Japan, including the development of biomass power plants, feed-in tariffs, and the use of waste wood and other biomass resources. Link: https://www.researchgate.net/publication/322798391_Development_of_Biomass_Power_Generation_Technology_in_Japan • Case study on biogas production in the UK: This case study examines the use of biogas as a renewable energy source in the UK, including the production of biogas from anaerobic digestion of organic waste, its use in combined heat and power systems, and the role of government policy in promoting biogas development. Link: https://www.researchgate.net/publication/312346847_The_role_of_biogas_in_the_UK_renewable_energy_mix • Case study on sustainable biomass production in South Africa: This case study provides an overview of sustainable biomass production in South Africa, including the use of biomass for energy production, the development of biomass-based industries, and the role of community-

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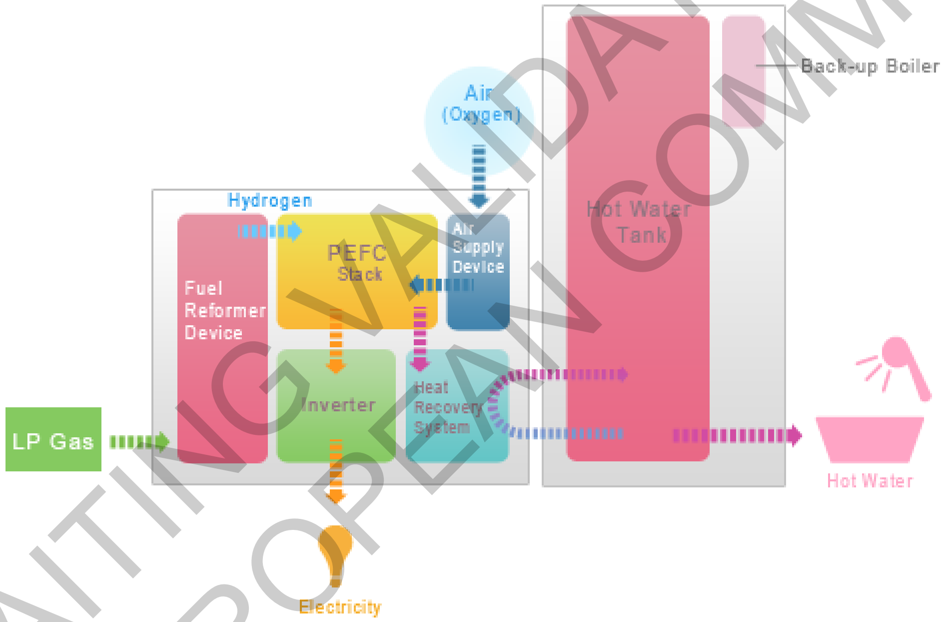
Sustainable biomass and biogas power	
	based organizations in promoting sustainable biomass production. Link: https://www.sciencedirect.com/science/article/pii/S1364032117304249 • Case study on biogas production in India: This case study examines the use of biogas as a renewable energy source in India, including the production of biogas from agricultural waste, its use in rural communities, and the challenges and opportunities for scaling up biogas production in the country. Link: https://www.sciencedirect.com/science/article/pii/S2352146520302033

3.2.6 Fuel cells

- Authors: **CARTIF**
- Knowledge Repository link: **https://netzerocities.app/resource-818**

Fuel cells
Fuel Cells (FC) are electrochemical devices that transform hydrogen and oxygen to obtain water and electrical power through an oxidation chemical reaction. FC are known as gas-to-power (or hydrogen-to-power) technologies. Unlike batteries, the reactive compounds are consumed continuously and produce electricity on-site:  *Figure: gas-fuel cell that produces hydrogen instantaneously and produces el. and heat in residential units in Japan https://www.j-lpgas.gr.jp/en/appliances/*   FCs are made of stacks that are formed by cells. The maximum generated electrical current and voltage depends on the cells and stacks configuration. Usually, **pure hydrogen obtained using previous reforming processes or electrolysis is supplied to the FC,** whereas some types of them include the hydrogen generation process internally, allowing the use of fuels such as methanol or methane.   The a**pplications of FCs are closely related to the operating temperatures and the availability of the reactive compounds**. The predominant technologies in the market are: • Proton-Exchange Membrane Fuel Cell (PEMFC). Based on platinum compounds. Their working temperatures are under 150°C. High-purity hydrogen is needed. PMFCs allow quick variations in the generated power and a high number of stops and starts, which is positive, especially in transport applications.

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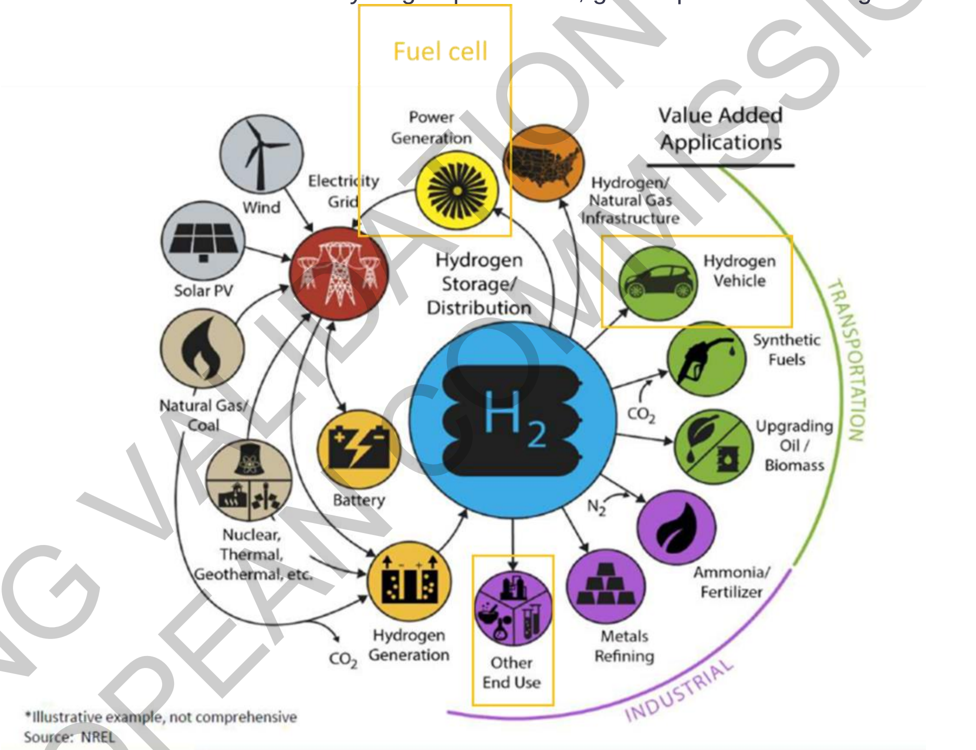
Fuel cells	
• Solid Oxide Fuel Cells (SOFC). Based on zirconium and nickel elements. SOFC works at very high temperatures in the range of 900°C, which allows the direct use of methane. This technology is designed for stationary applications with a low number of stops and starts, such as power generation or building cogeneration. (Such as the one in Japan above). • Phosphoric acid fuel cell (PAFC). The operational temperature is in the range of 190-250°C, allowing the employment of certain reformed gases. The main application of PAFC is building cogeneration. The costs of FCs technologies are high due to the low market penetration, being in the range of 2000 €/kW depending on the kind and size of the system. However, high growth rates in the development and adoption of FC are foreseen in the next years.	
CO-BENEFITS	Reduce GHG emissions, since the reaction do not produce CO_2 and the Hydrogen can be obtained using renewable sources. Due to the same reason, it increases access to clean, affordable, and secure energy and contributes to decrease fossil-fuel dependency since availability of the fuel is not restricted to certain countries
KEYWORDS	Fuel cells are connected to: hydrogen production, gas-to-power technologies: 
EXTERNAL LINKS	• https://pace-energy.eu/japan-a-success-story-in-deploying-fuel-cell-micro-cogeneration/ • http://www.hysafe.org/science/eAcademy/JSSFCH/.JSSFCH2012/Steinbeis

Fuel cells	
PRE-CONDITIONS & ENABLING CONDITIONS	***Climate and geography:*** The climatic and geographic conditions of a region can affect the efficiency and performance of fuel cells in several ways. For example, extreme temperatures can decrease the efficiency of the electrochemical reaction inside the fuel cell, reducing the amount of electricity produced. Furthermore, the availability and cost of hydrogen in each region can also impact the feasibility and viability of using fuel cells on a large scale. Additionally, since the production of green hydrogen depends on the renewable generation and that, at the same time, depends on the climate

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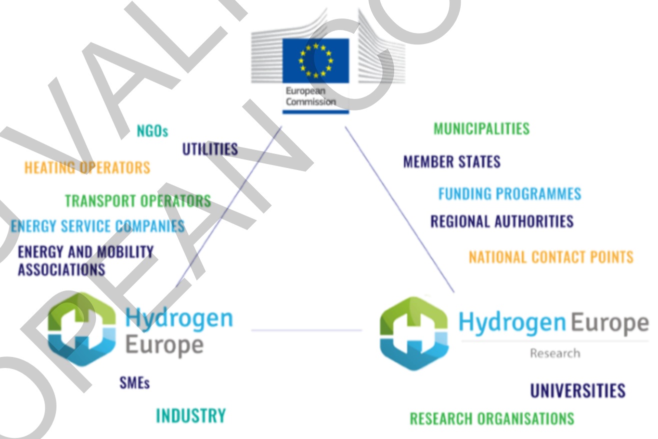
Fuel cells	
	conditions, the availability of hydrogen could be restricted in certain places or during certain seasons [6] ***Technical aspects/infrastructure:*** Adequate and reliable sources of hydrogen, such as renewable energy or natural gas with carbon capture and storage need to be implemented. A hydrogen supply and distribution network, including pipelines, trucking, and storage facilities[7]. In certain cases, DSOs and TSOs must approve the right to feed electricity into the distribution grid. ***Policy and regulatory/legal framework:*** Incentive programs and subsidies to reduce the upfront cost of fuel cell technology and encourage adoption by consumers and businesses. Policies that support the development of a hydrogen infrastructure, including production, distribution, and storage facilities. Availability of technical standards and regulations that ensure the safety, reliability, and performance of fuel cells and hydrogen systems. Programs and initiatives (e.g. in Spain PTE HPC, in Europe The Clean Hydrogen Join Undertaking partnership) that promote research and development of fuel cell technology and support innovation in the field. Public education and awareness campaigns to inform the public about the benefits and potential of fuel cells. ***Economic and social context:*** Competitive and affordable price for fuel cell technology, adequate funding and support for research and development, and public education and awareness programs. In addition, it is important to have policies and regulations that promote the deployment and integration of fuel cells into the energy system, and to ensure that the benefits of using fuel cells are shared equitably among different social groups.  *Figure: The three members of the Clean Hydrogen Join Undertaking are the European Commission, fuel cell and hydrogen industries represented by Hydrogen Europe and the research community represented by Hydrogen Europe Research*

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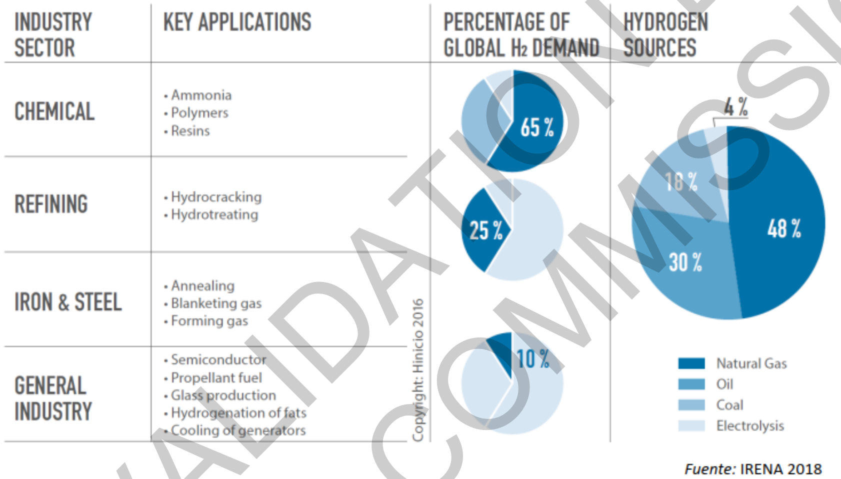
6 M. A. Salam *et al.*, 'Effect of Temperature on the Performance Factors and Durability of Proton Exchange Membrane of Hydrogen Fuel Cell: A Narrative Review', *Mater. Sci. Res. India*, vol. 17, no. 2, pp. 179–191, Sep. 2020, doi: 10.13005/msri/170210

7 European Network of Transmission System Operators for Gas, Gas Infrastructure Europe, and Hydrogen Europe, 'How to transport and store Hydrogen - Facts and Figures', May 2021. [Online]. Available: https://entsog.eu/sites/default/files/2021-05/ENTSOG_GIE_HydrogenEurope_QandA_hydrogen_transport_and_storage_FINAL_0.pdf

This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

Fuel cells	
CONSTRAINTS/ BARRIERS for implementation	**High cost** of fuel cell technology compared to other forms of energy generation. The usual range of cost for a FC is around 4000 €/kW, while the cost of a PV plant is around 1600 €/kW[8]. This high cost is due to the high price of materials and the low production volume of fuel cells[9]. However, the cost is highly dependent on the nominal power of the FC. **Lack of infrastructure** for the distribution and storage of hydrogen, which is the main fuel used in fuel cells, and the cost of introducing a new infrastructure in parallel to gas pipelines adapted to hydrogen. The refurbishment of natural gas pipelines to make them available to transport hydrogen without the need of constructing new ones is still under research. **Durability and performance** of fuel cells, especially in extreme conditions [10] **Lack of public awareness** and understanding of fuel cell technology, which can hinder the adoption of fuel cells by consumers and businesses. 
INSTRUMENTS/ Processes for implementation	• User Engagement for Energy Performance Improvement https://netzerocities.app/resource-1498 • Capacity building and training https://netzerocities.app/resource-1578 • Educational/ Capacity building barriers identification https://netzerocities.app/resource-1588 • Loans for Energy Efficiency (EE) https://netzerocities.app/resource-1648 • Blended finance for Energy Efficiency (EE) https://netzerocities.app/resource-1658 • Integrated climate plans for cities https://netzerocities.app/resource-1698 • Governance EU Climate Neutrality Framework https://netzerocities.app/resource-1728 • Turnkey Retrofit Service https://netzerocities.app/resource-1843 • One-stop-shop for building renovation https://netzerocities.app/resource-1913
DRAWBACKS/ ADVERSE IMPACTS of the	While the massive implementation of fuel cells in cities can have many benefits, such as reducing emissions and improving air quality, there are also potential drawbacks and adverse impacts to consider. Some of the potential drawbacks and adverse impacts of a future massive implementation of fuel cells in cities include:

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8 P. Marocco et al., ‘A study of the techno-economic feasibility of H2-based energy storage systems in remote areas’, Energy Convers. Manag., vol. 211, p. 112768, May 2020, doi: 10.1016/j.enconman.2020.112768.
9 Electrocatalysis Consortium, ‘Accelerating the Deployment of Fuel Cell Systems’, *PGM-free electrocatalysts for next-generation fuel cells and electrolyzers*. https://www.electrocat.org/ (accessed Dec. 15, 2022).
10 M. A. Salam et al., ‘Effect of Temperature on the Performance Factors and Durability of Proton Exchange Membrane of Hydrogen Fuel Cell: A Narrative Review’, Mater. Sci. Res. India, vol. 17, no. 2, pp. 179–191, Sep. 2020, doi: 10.13005/msri/170210.

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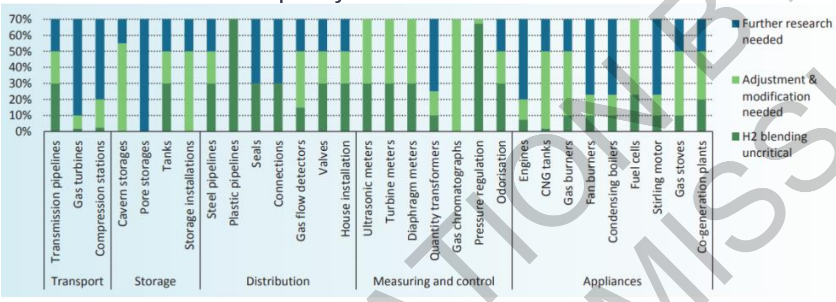
<table>
<tr><th colspan="2">Fuel cells</th></tr>
<tr><td>solutions after implementation</td><td>

- High upfront cost: Fuel cell technology is currently more expensive than other forms of energy generation, which can make it challenging for consumers and businesses to adopt. The usual range of cost for a FC is around 4000 €/kW, while the cost of a PV plant is around 1600 €/kW.
- Dependence on hydrogen: Fuel cells rely on hydrogen as a fuel, which means that the widespread adoption of fuel cells could lead to increased demand for hydrogen production and infrastructure.
- Safety concerns: Hydrogen is highly flammable and can pose safety risks if not handled properly. The large-scale deployment of fuel cells and hydrogen infrastructure could raise concerns about safety and accident prevention. However, if hydrogen is blended with a concentration less than 20%, that does not significantly affect gas quality, safety, risk, materials, and network capacity.[11].



Source: Deutscher Verein des Gas- und Wasserfaches (2013), Entwicklung von Modularen Konzepten zur Erzeugung, Speicherung und Einspeisung von Wasserstoff und Methan in Erdgasnetz.

- Environmental impacts: While fuel cells do not produce greenhouse gas emissions when operating, the production of hydrogen from fossil fuels can result in emissions. In addition, the disposal of spent fuel cells can generate waste and pollution.
- Socioeconomic impacts: The deployment of fuel cells and hydrogen infrastructure could have impacts on the economy and society, such as job creation and displacement, and changes in energy pricing and availability.

Overall, while fuel cells have the potential to play a key role in the transition to a clean energy future, it is important to carefully consider the potential drawbacks and adverse impacts of a massive implementation of fuel cells in cities.

Regarding specific case studies:

- Ene.field project. The project brought together European micro FC-CHP manufacturers to deliver and monitor trials across all the European domestic heating markets, dwelling types and climatic zones. The project found that the two main aspects to be improved in the installation of FC are the running costs and the ease of use of the technology.
- PACE-Energy project is aimed to unlock the large-scale European deployment of Fuel Cell micro-Cogeneration in private homes. In this case, the project found that the administrative procedure requested by some DSOs and TSOs may hinder the FCs implementation processes.

</td></tr>
<tr><td>IMPACTS (Indicators & DNSH)</td><td>

Economic and social context:
The massive implementation of fuel cells in cities can have positive economic and social impacts, such as reducing reliance on fossil fuels, creating jobs in the clean energy sector, and improving air quality.

</td></tr>
</table>

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11 M. J. Chae, J. H. Kim, B. Moon, S. Park, and Y. S. Lee, 'The present condition and outlook for hydrogen-natural gas blending technology', *Korean J. Chem. Eng.*, vol. 39, no. 2, pp. 251–262, Feb. 2022, doi: 10.1007/s11814-021-0960-8

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Fuel cells	
	Ene.field project: • GHG savings: 370 – 1100 kg CO_2 per kW of micro-CHP per year • Compared to a gas condensing boiler in a partially renovated semi-detached single-family home located in Germany, they found CO_2 emission savings by a generic FC-µCHP system of 33%. • Emission savings of between 45% and 50%, depending on the FC type, when the electricity production mix replaced is as carbon intensive as a hard coal fired power plant and the heat-led FC-µCHP systems run up to 5333 full load hours per year • FC-µCHPs lead to 6-26% lower GHG emissions, 7-49% lower resource use, 21-65% lower particulate matter induced impacts, 25-73% lower acidification impacts and 54-118% lower water uses. The upper values usually correspond to new buildings located in southern Europe (low heat demand), while the lower values usually correspond to existing buildings located in northern Europe (high heat demand). REMOTE project: 410 €/MWh unit cost for the fuel-cell-based H2 energy-storage in a power-to-power solution* over 10 years, compared to 864 €/MWh for a new 20-km cable connection to the grid. *The Power-to-Power solution is the combination of Power-to-Gas (electrolyser to produce hydrogen and store it) and a Gas-to-Power (fuel cell consuming h2 from storage) technologies using hydrogen as energy storage system.

3.2.7 Waste heat recovery in district heating networks

- Authors: **POLIMI**
- Knowledge Repository link: **https://netzerocities.app/resource-858**

Waste heat recovery in district heating networks
District heating (DH) is an energy infrastructure that distributes centrally generated heat to the consumers (buildings). One of the main advantages of DH lies in its ability to recover and reuse heat that would otherwise be wasted by distributing it to customers provided that the temperature levels are appropriate. Waste heat recovery becomes essential in the decarbonisation path of the energy system. The main benefit consists in bringing energy efficiency at urban scale by substituting the energy delivered by individual heating system with the distribution of already available waste heat form industrial processes. The amount and cost of recovery depends on several factors: • quantity of dissipated heat • quality of the effluent and its temperature • temperature required by the heat demand • technology to recover heat • temporal correspondence between waste heat availability and heat demand • distance of the waste heat sources from the heat demand In general, there is a great amount of waste heat to be easily recovered and the consequent potential reduction of emissions through sectoral integration is very significant.

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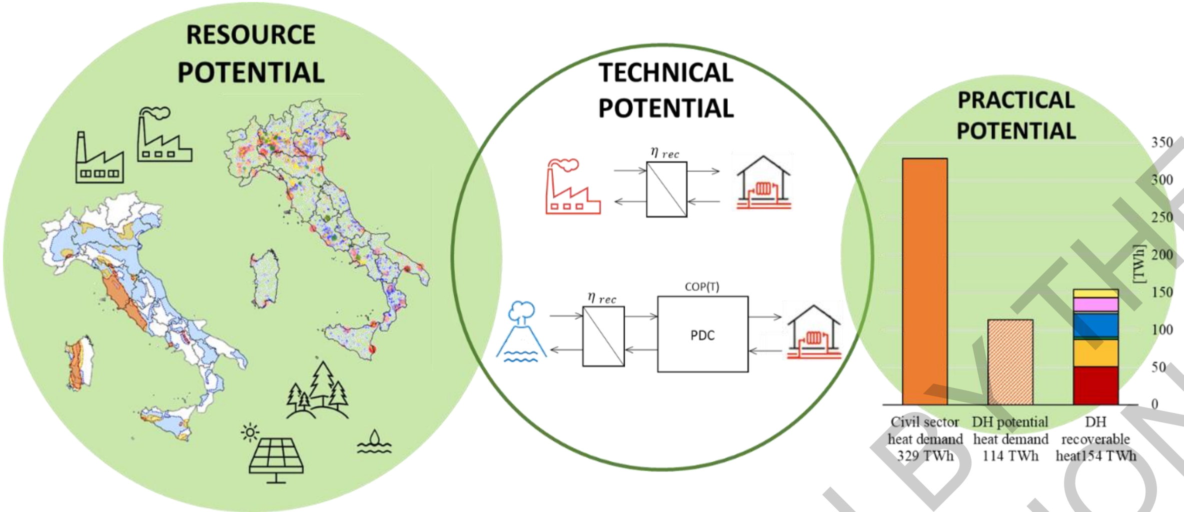
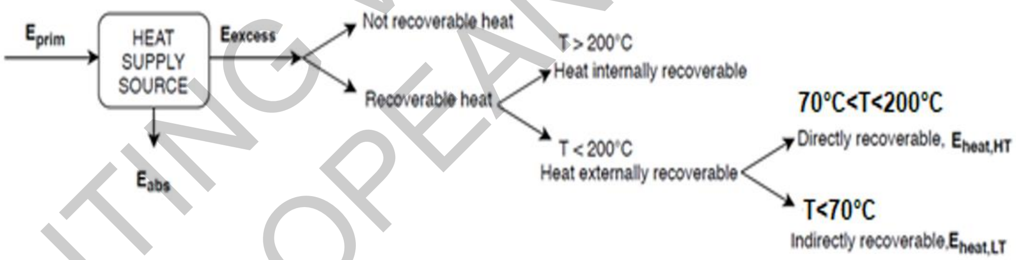
Waste heat recovery in district heating networks	
 Unfortunately, the practice shows that, up to now, it is difficult to make it use less for technical reasons but most of all for management and business model lacking. There are some technical aspects to be carefully analysed in order to enable the realisation of waste heat recovery, primarily the temperatures and network design parameters (flows and pipe diameters) should be compatible with the heat integration. Therefore, existing DH systems must be adapted and new DH systems must be specially designed to enable waste heat recovery from the existing sources. In the past, the supply temperature of DH systems was 70 to 90 °C or more, the low-temperature DH systems have been implemented with 40 to 60 °C and the 5th generation of DH systems consists of cold district heating networks with about 10 to 20 °C, which is used as a heat source for decentralized installed heat pumps. The waste heat can only be used, if the supply temperature of the DH network is below the temperature of the waste heat. 	
CO-BENEFITS	The recovery of waste heat in DH allows the reduction of fossil fuels consumptions and therefore of GHG emissions while increasing the access to clean, affordable, and secure energy
EXTERNAL LINKS	• Article - Waste heat Italy https://reader.elsevier.com/reader/sd/pii/S2666955221000083?token=D2C0967BA30FF3777EC07B334A94AC47F10036A2ABE6216A5F40F120B95DBADFB63252689C0A016D0F226DCEE25EC8E8&originRegion=eu-west-1&originCreation=20220412092127 • https://eurec.be/waste-heat-is-a-sustainable-source-for-district-heating-networks/ EU projects: • Reuse heat https://www.reuseheat.eu/ • Rewardheat https://www.rewardheat.eu/en/ • SoWhat https://sowhatproject.eu/

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Waste heat recovery in district heating networks	
PRE-CONDITIONS & ENABLING CONDITIONS	Ideally, to foster the integration of waste heat and renewable energy in district heating (DH) systems, the city should present a dense built environment and buildings with a centralized heating system that can be easily converted into a DH substation. Refurbished and adaptable buildings would be easier to be connected to a DH network at low temperature and reduced distribution temperatures enables the utilization of a wider range of possible technologies and heat sources to be used. Therefore, an adequate built environment will make thing easier for waste heat recovery and renewable energy sources. This can be influenced by the conformation of the territory under study and thus by the presence or not of waste heat sources in the proximity of heat demands or already existing distribution networks. Also, the role of decision-making authorities, such as policy makers and cities' mayors, is very relevant, with a well-made spatial planning and with a long-term vision. So that they can make appropriate choices and investments, it is essential that they have a comprehensive view of the urban energy system. They should be aware of what is the potential of DH in their area of interest and what are the benefits that can be reached, such as reduced greenhouse gases emissions, independence from fossil fuels and carbon-based energy markets, sustainability, security of supply, etc. Moreover, it is essential a good communication among all the involved parties, thus policy-makers, DH operators, owners of waste heat sources such as industries and district users, thus citizens. They should also try to create a favourable environment for DH uptake by considering the competitiveness of DH with respect to other heating alternatives, and thus avoiding, for example, to incentivize fossil-fuelled based technologies such as CHPs.[1] Regarding the legal framework, the model of ownership that has demonstrated to be the most effective for DH system is the municipal/cooperative model. Denmark, where DH market share is among the highest in the world, can serve as an example in this sense. In 2019, municipally and cooperatively owned district heating companies supplied approximately 93% of the heat sold in Denmark, with the remaining 7% given by private companies [2]. [1] K. Lygnerud, E. Wheatcroft, and H. Wynn, "Contracts, business models and barriers to investing in low temperature district heating projects," Appl. Sci., vol. 9, no. 15, 2019, doi: 10.3390/app9153142. [2] K. Johansen and S. Werner, "Something is sustainable in the state of Denmark: A review of the Danish district heating sector," Renew. Sustain. Energy Rev., vol. 158, no. December 2021, p. 112117, 2022, doi: 10.1016/j.rser.2022.112117.
CONSTRAINTS/ BARRIERS for implementation	One of the main aspects that can hinder the implementation of district heating based on waste heat recovery and renewables is the lack of information and capacity to generate an effective large-scale and long-term urban planning, that can be able to take into considerations the local nature of district heating together with its international and global implications. This double nature of DH (local and global) makes it difficult to comprehensively analyse and assess its potential. A research gap is identified in methodologies and instruments able to comprehensively analyse and assess district heating potential. Indeed, the existing broad energy system models cannot represent the complexity of an urban area, and in the main time the outcomes of the existing detailed local models cannot be reflected in the higher scale of analysis. Together with urban planners, a lack of knowledge of the other involved parties, such as owners of waste heat sources, DH operators and users, is to be stressed. They may not be aware of the opportunities district heating can bring and this can lead to a not favourable opinion of DH: waste heat owners such as industrial companies can be uninterested in being part of a DH systems and citizens may

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Waste heat recovery in district heating networks	
	consider their connection to a district heating network not convenient. The divergent view that heat owner and DH companies can have is another big obstacle. Another barrier for DH implementation and diffusion is therefore the lack of a well-established regulatory framework, which can push towards a fully decarbonized heating system and that can regulate the market in order to achieve energy equity and security of supply. Other obstacles of technical nature may be: • The lack of waste heat sources in the proximity of the existing DH network or of the area to be heated • The impossibility to recover the available heat because of not adequate temperature levels • The temporal mismatching between heat availability and heat demand • The fluctuating and not controllable nature of renewable sources and other waste heat sources that can may not ensure a constant supply of heat.
INSTRUMENTS/ Processes for implementation	Instruments and activities to be developed and investigated to foster district heating uptake, especially with low temperature distribution networks based on waste heat and renewable sources, are: • Models and methodologies able to address the intermediate level of analysis and to fill the identified research gap between large-scale and small-scale levels. • Capacity building of all the involved parties to assure them a proper overview on DH and waste heat recovery. There could be tutoring, dissemination and communication activities, for example between researchers and DH operators, between DH operators and users, and between policy-makers and urban planners. Also users should be trained in how to properly operating their heating system, for example by well setting in-building temperatures. A way to promote their good behaviour can be the introduction of reduced tariffs in case they guarantee a temperature on the return pipe of the distribution network that is below a certain threshold. This is indeed a practice implemented in Denmark. • Proper urban spatial planning, definition of long-term strategies, policies and market regulatory framework. It is important that both investors and customers are incentivized to behave properly, without conflicting actions that can damage one another. • Introduction of incentives to make investments more attractive and affordable and/or the introduction of taxes or increased costs for CO_2 emitting technologies. [1] [1] K. Lygnerud, E. Wheatcroft, and H. Wynn, “Contracts, business models and barriers to investing in low temperature district heating projects,” Appl. Sci., vol. 9, no. 15, 2019, doi: 10.3390/app9153142.
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	The main problems that can arise in DH networks based on waste heat recovery may be due to an improper handling of the systems. Indeed, what has been generally noticed is that even if a system has been well designed and built, it can bring adverse impacts in the energy system and in the society due to errors in operations. The latetrs can be addressed to both DH operators and costumers. For example there can be temperature levels, mass flow rates and pressure values along the distribution and transmission network that are far from the design conditions. One example is the EU-EIT Climate-KIC project called Merezzate+ (https://www.merezzateplus.it/).

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Waste heat recovery in district heating networks	
IMPACTS (Indicators & DNSH)	***DNSH:*** The environmental goals that should not be armed according to the DNSH principle are six: 1. Climate change mitigation 2. Climate change adaptation 3. Sustainable use and protection of water and marine resources 4. Transition to the circular economy, including waste prevention and recycling 5. Prevention and reduction of air, water and soil pollution 6. Protection and restoration of biodiversity and health of ecosystems. District heating's features makes it a technology that can intrinsically lead to the fulfilment of these principles. Indeed, it is able to efficiently distribute recovered waste heat otherwise wasted, with a consequent reduction in primary energy (and fossil fuel) consumption, and avoided greenhouse gases emissions. In this sense it can mitigate the climate change and it is also adaptable to integrate a wide range of renewable energy sources. Since it is a large-scale infrastructure with a strong local nature, DH is potentially able to properly exploit the resources available on the territory. With a well-done spatial and energy planning, the exploitation of natural resources such as soil and water can be done without causing an increased pollution of them. And in the same way, this can be done for the protection of the ecosystem. Moreover, being an infrastructure that connects many different energy consuming sectors, namely the heating sector (with the buildings), the power sector (with the large-scale heat pumps and the CHP plants), the industry, the telecommunication network (with datacenters), etc., DH also has a central role in sector coupling and circular economy. Again, it must be stressed that all these intrinsic benefits that DH can bring can be reduced or even reversed if a proper spatial planning and a good energy strategy are not done. Its strengths may become problems if not well addressed, both in the planning and in the operating phase. Specific identified risks that may infringe the DHNS principle is the noise pollution that can be envisaged as a consequence of the market uptake of heat pumps, both in large-scale and small-scale applications.
Additional information from CASE STUDIES	From the case study illustrated in [4] it can be stressed that at the basis of a more detailed research for DH potential assessment stands the strong interest showed by the local administration in transitioning towards a greener and more sustainable energy mix to supply thermal energy in the existing DH network. The knowledge and the spatial characterization of the urban area then highlighted favourable local conditions for the uptake of waste heat-based DH. [4] G. Spirito, A. Dénarié, V. F. Cirillo, F. Casella, J. Famiglietti, and M. Motta, "Energy mapping and district heating as effective tools to decarbonize a city: Analysis of a case study in Northern Italy," Energy Reports, vol. 7, pp. 254–262, 2021, doi: 10.1016/j.egyr.2021.08.147.

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3.2.8 Electricity storage: Chemical storage

- Authors: **Tecnalia**
- Knowledge Repository link: **https://netzerocities.app/resource-868**

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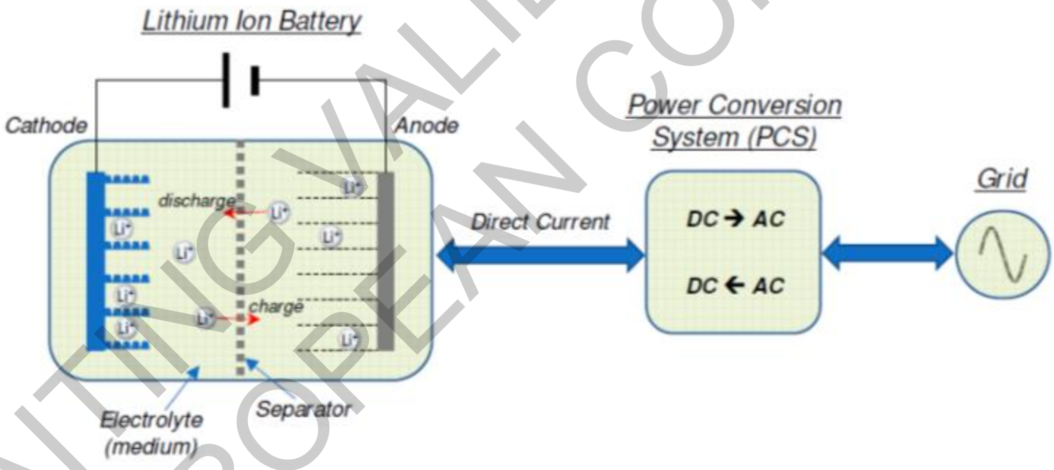
Electricity storage: Chemical storage

Chemical storage refers to storing electricity that can be released as required though chemical processes. Known also as **batteries** that can act as chemical energy storage and become future energy generation solutions more efficient and profitable. They are especially interesting for **intermittent renewable sources** (e.g. solar or wind energy generation) for making efficient use of the availability.

There are nowadays different types of batteries. Follows up a non-exhaustive list of typologies with the aim of providing a general outlook:

- **Lithium-Ion batteries** are the fastest growing battery type for industry and residential use. They can store high amounts of energy and are highly efficient, operating under a wide range of temperatures. However, their lifespan is not good enough and needs to be improved.
- **Lithium-Ion Polymer batteries** they have a longer lifespan and better safety record keeping high-energy efficiency. However, they are uneconomical in many cases.
- **Lead-Acid batteries** can be designed to power large-scale applications and are relatively cheap, safe, and reliable. They are already used in large storage and uninterrupted power supply solutions (e.g. powering backup generators). Their problem is that they are rather large, heavy, and can't be moved. Moreover, their performance under cold temperatures is not good and they have a short life cycle.
- **Flow batteries** in this case unlike conventional battery systems, the energy output is independent of the energy storage capacity which depends on the size of the tank. Their energy output ratio to weight can be up to three times better than lead-acid batteries but they are less efficient.
- **Sodium Sulphur batteries** uses liquid sodium and sulphur as electrolytes. This composite has very high energy and power density as well as a long cycle and can be produced from inexpensive materials. But they need high temperatures for operation (about 300-350ºC) and therefore require energy to keep them operational. Furthermore, they are highly corrosive and cells must be kept stationary.



Source: OnLocation

CO-BENEFITS	The direct co-benefit will be in the field of climate mitigation by helping to reduce GHG emissions. However, this is a whole new industry that is promoting economy and entrepreneurship. Not only for the fabrication but also for the maintenance and circularity process inherent to such a type of solutions.
EXTERNAL LINKS	• TR-HP Project: https://www.tri-hp.eu/

Electricity storage: Chemical storage

PRE-CONDITIONS &	Electricity storage requires a surplus generation for storage and is especially relevant for intermittent renewable energy sources (photovoltaic or wind energy).

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Electricity storage: Chemical storage	
ENABLING CONDITIONS	There are several types of batteries but in general optimal operation conditions require mild temperatures although between -5ºC and 35ºC most of them work properly. Below -5ºC and over 35ºC problems may arise shortening battery life, degradation of components, decreasing usable capacity, sulphation in lead-acid batteries, etc. The storage system will need direct connection to the generation site or to the grid and similarly will need to be connected to the grid and/or user of the stored energy (heat pump, building, etc.). Batteries are a modular solution although many times linked with the size. Therefore, bigger capacity requires more space, and, in some cases, this may limit the application of specific types of batteries, according to the energy density (some buildings with space limitations for example). The demand for (stationary) energy storage is already clear now, and will keep increasing along with the penetration of renewables in electric grids. The business case for large-scale deployment of batteries will improve accordingly. Payback periods may vary depending on regulatory frameworks, but low periods are achievable.
CONSTRAINTS/ BARRIERS for implementation	There are several barriers and constraints for implementation. Among others it should be considered: • **Safety:** there are safety issues both with small and large storage batteries. With incidents of exploding phone batteries or Tesla car batteries catching fire, spontaneously or after a car crash. In this regard, novel batteries with safe and environmentally friendly chemistry are currently under development. • **Impact of regulation on the business case:** From market design establishing service and operation framework to tariffs regulation and support incentives. • **Scarcity of raw materials (effect on prices):** Most common solutions require valuable metals such as lithium, nickel, cobalt, iridium, vanadium or graphite which are increasingly scarce. This affects not only to its price but also to its mining conditions due to locations (Republic of Congo for instance). • **Efficiency of systems:** There are losses on the storage that sometimes make the system inefficient. • **End of life:** The battery lifespan depends on several factors, such as material degradation, applications, and number of recharging cycles. Although improvements have been made yet they do have a limited life. Considering that the chemicals used are hazardous for the environment and scarce, recycling of key battery components is crucial to ensure a circular economy approach. However, there are technical and economic limitations that risk the business case.
INSTRUMENTS/ Processes for implementation	For their implementation, regulation and business model are the key questions. Therefore, any instrument that will help achieve expected results in these fields is helpful. • Loan for Energy Efficiency (https://netzerocities.app/resource-1648) to provide soft funding • Blended finance for Energy Efficiency (https://netzerocities.app/resource-1658) • Local energy communities (https://netzerocities.app/resource-618) where storage solutions may increase self-consumption • Integrated land use and urban planning with energy and climate (https://netzerocities.app/resource-1678) for introducing specific measures to foster the use of electricity storage

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Electricity storage: Chemical storage	
	• Integrated climate plans for cities (https://netzerocities.app/resource-1698) for considering storage as one of the solutions towards energy transition. • User engagement for energy performance improvement (https://netzerocities.app/resource-1498) to get private citizen involvement • One-stop-shop for building renovation (https://netzerocities.app/resource-1913) for understanding how storage can be part of the whole solution.
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	As explained lifespan depends on the number of recharging cycles and their characteristics. Wrong recharging systems may reduce the performance and require battery replacement sooner than expected.
IMPACTS (Indicators & DNSH)	Impacts depend on typologies. Considering load profile of a multi apartment building in Gothenburg and the PV production profile under local weather condition three different types of batteries have been analysed: lead acid, NaNiClo (Sodium-Nickel-Chloride) and Lithium Ion. The analysis showed the Lithium ion battery system is superior in achieving higher Self-Sufficiency Ratio with the same Life Cycle Cost (https://doi.org/10.1016/j.egypro.2016.06.025). Other publications on this: • Impact of residential battery energy storage systems on the peak reverse power flows from distributed photovoltaic systems - ScienceDirect • The impact of battery storage technologies in residential buildings with sub-daily autonomy and EV contribution Regarding costs it must be said that at least in the case of Lithium Ion batteries and due to its use in Electric Vehicles the cost of this battery packs has fallen from approximately 1.000 USD/kWh in 2010 to 176 USD/kWh in 2018. Most analysts, including auto manufacturers, project more reductions, reaching 100 USD/kWh around 2025 and 62-72 USD/kWh by 2030. The drop-in prices will make easier to obtain better payback periods and massive roll-out not only in electric vehicles but also in households.
	From the DNSH point of view it must be said that batteries lead to greenhouse gas emissions on their lifecycle due to the energy-intensive nature of battery production and the associated mining processes. There are concerns around the impact of mining lithium, cobalt, nickel, graphite and other materials for this growing economy. Furthermore, these mining processes are also associated to: • Poor labour conditions in developing countries (almost 50% of the world cobalt production takes place in Republic of Congo for example). • Extensive use of water in the mining process • Health impacts derived of mineral extraction. For instance, in China there have been reports of graphite rain. And obviously depends on the energy stored. For instance, in the case of electric vehicles charged by regular grid compared to combustion engines there is, considering lifecycle, a reduction of around 20-30% of emissions (depending on the mix of the grid). If charged only with renewables then the reduction is close to 70%. However, in the case of shared households batteries will be connected and interact with the grid, and they can also provide additional buffering capacity to the grid. Moreover, the same battery technologies, if installed at power plants, can support grid stability and peak shaving. As explained, batteries have hazardous elements that should be recycled. However due to economic and technical limitations large scale recycling is not solved yet.
Additional information from CASE STUDIES	Some European projects related as: TILOS SCORES and STORY Horizon 2020

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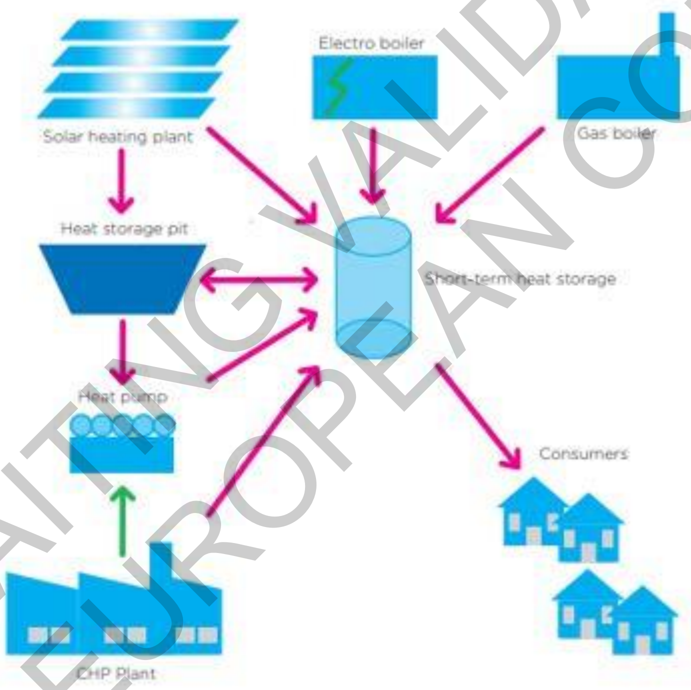
This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

3.2.9 Thermal energy storage

- Authors: **REGEA**
- Knowledge Repository link: https://netzerocities.app/resource-828

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the "orange" fields of this solution, and then it has been afterwards reviewed by JRC and completed the "pink" fields, and the Knowledge Repository content has been updated with JRC's input. So, here only the "orange" fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

Thermal energy storage
Thermal energy storage (TES) is a temporary storage of energy by heating or cooling a storage medium so that the stored energy can be used at a later time for power generation and heating and cooling application. Thermal energy storage provides the essential **flexibility** to **integrate high shares of solar and wind power**. Heat/cold produced at times of peak supply of renewable electricity can be used to meet demand even when the sun is not shining and the wind is not blowing. TES use in **district heating and cooling** effectively decouples demand from supply, allowing energy to be stored on a seasonal basis. District heating already incorporates sensible heat technologies such as tank TES (or TTES) and underground TES (or UTES).   Block diagram of a large-scale heat storage pit/seasonal heat storage.      *Source: Heat storage pits, Ramboll (*https://ramboll.com/-/media/files/rgr/documents/markets/energy/ghi/heat-storage-pit_oct_2020_resized.pdf*)*   [Seasonal heat storage]() technologies allow **heat delivery to residential areas** by thermal heat networks to make much better use of regional sustainable heat sources, thereby reducing the need for fossil fuels for peak demand.   TES can further enable **winter heating demands** to be met through thermal energy stored from sunny summer days, and **cooling demands in summer** to be met through cold stored from winter. TES enables whole system benefits through increased sector integration, allowing renewable electricity to

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Thermal energy storage	
reliably meet a greater proportion of energy demand. By supporting the shift to renewables, efficiency and greater electrification, TES investments can help to fulfil long-term climate and sustainability goals.	
CO-BENEFITS	Thermal storage enables the use of electricity during the peak of supply, and therefore **reduces the energy needs** during the time of low supply. With its wide variety of applications, it increases **access to clean, affordable, and secure energy.** It enables renewable electricity to reliably meet a greater proportion of energy demand, which **reduces GHG emissions, and improves air quality.**
EXTERNAL LINKS	• Innovation Outlook: Thermal Energy Storage (IRENA) • Thermal energy storage: an overview

3.2.10 Seasonal storage (pits, dwells, etc.)

- Authors: **TNO**
- Knowledge Repository link: **https://netzerocities.app/resource-848**

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the “orange” fields of this solution, and then it has been afterwards reviewed by JRC and completed the “pink” fields, and the Knowledge Repository content has been updated with JRC’s input. So, here only the “orange” fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

Seasonal storage (pits, dwells, etc.)
Heat supply and demand deal with a seasonal mismatch; year round supply (e.g. from geothermal systems, industrial waste heat) or if supply particularly in summertime (e.g. solar energy) does not match the low heat demand in summer and high demand in winter. Various technologies have been studied and tested in field labs and pilots, such as Aquifer Thermal Energy Storage (ATES), Borehole Thermal Energy Storage (BTES), Pit Thermal Energy Storage (PTES), Mine Thermal Energy Storage (MTES) and Tank Thermal Energy Storage (TTES). **These seasonal heat storage technologies allow heat delivery to residential areas by thermal heat networks to make much better use of regional sustainable heat sources, thereby reducing the need for fossil fuels for peak demand.** The suitable technology and design of the UTES system is highly dependent on the regional subsurface characteristics and the design and characteristics of the thermal heat network with its regional heat source(s) and consumers. For example, for new, well-insulated buildings with underfloor heating, shallow, less costly, and low-temperature UTES systems suffice. For older buildings with poor isolation and central heating, deeper and costlier high-temperature UTES systems are needed.

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Seasonal storage (pits, dwells, etc.)

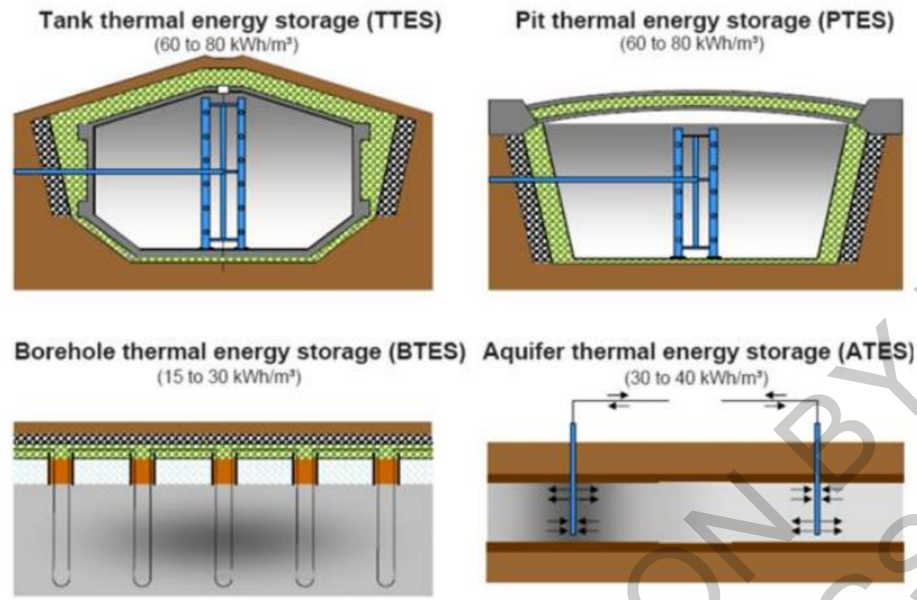
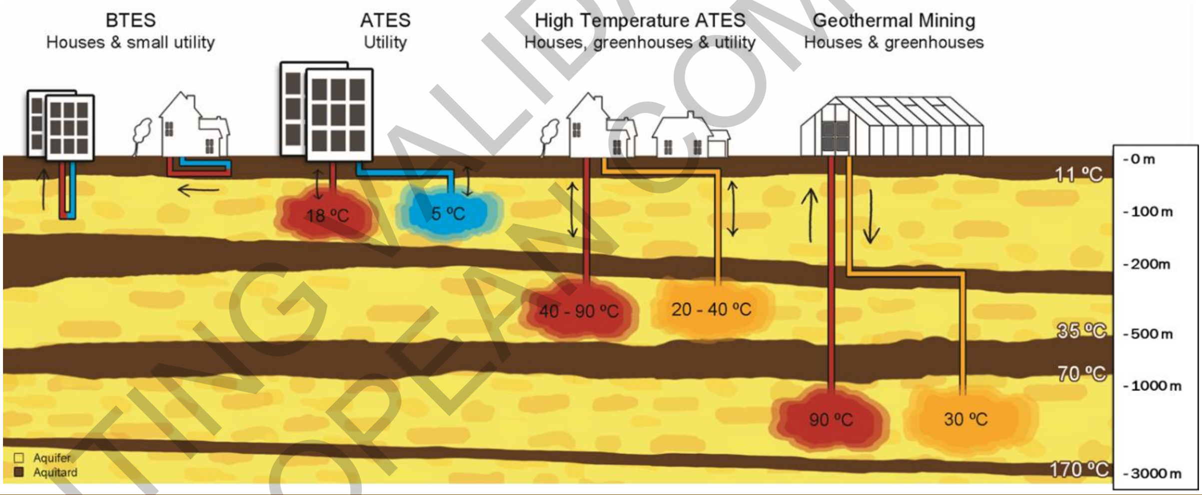


Figure 1: Concepts of thermal energy storages (Source: Steinbeis Forschungsinstitut Solites)

Figure: concepts of thermal energy storage: Tank thermal energy storage, pit thermal energy storage, borehole thermal energy storage and aquifer thermal energy storage (see https://tracer-h2020.eu/wp-content/uploads/2019/10/TRACER_D2.1-Heat-Storages.pdf*)*



CO-BENEFITS	The increased use of sustainable or waste heat sources and the added flexibility of the heat supply using the buffer allows increased access to clean, affordable, and secure energy and reduces GHG emissions.
KEYWORDS	Direct: Underground thermal energy storage, RES Heating and Cooling (heat pumps, free cooling, Geothermal (for heating and cooling)), From 3G to 5G district heating and cooling networks (generation to substations) Indirect: Storage solutions, major renovations built environment (e.g. also for older buildings), (nearly) zero energy buildings
EXTERNAL LINKS	• https://www.heatstore.eu/documents/HEATSTORE_UTES%20State%20of%20the%20Art_WP1_D1.1_Final_2019.04.26.pdf • https://tracer-h2020.eu/wp-content/uploads/2019/10/TRACER_D2.1-Heat-Storages.pdf • HEATSTORE project www.heatstore.eu (see also 'download' section for interesting documents) https://energy.nl/data/aquifer-thermal-energy-storage-storage-temp-c2-b15-to-c2-b125-e1-b5-92c-individual-system

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Seasonal storage (pits, dwells, etc.)	
EXAMPLES	• Okotoks Canada with ground thermal storage and solar thermal for a district heating network: http://www.dlsc.ca/ • Vojens pit storage http://solarheateurope.eu/2020/05/19/vojens-district-heating/

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3.2.11 From 3G to 5G District Heating and Cooling networks (generation to substations)

- Authors: **TNO**
- Knowledge Repository link: **https://netzerocities.app/resource-878**

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the “orange” fields of this solution, and then it has been afterwards reviewed by JRC and completed the “pink” fields, and the Knowledge Repository content has been updated with JRC’s input. So, here only the “orange” fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

From 3G to 5G District Heating and Cooling networks (generation to substations)
A district heating system transports warm water from an external heat source to several buildings for space or tap water heating. Used water will flow back to the source to be heated again. Several generations of heat networks can be distinguished, mainly defined by the temperature of the water. A 3rd generation network can deliver temperatures up to 100 degrees Celsius, a 4th generation network between 40-70 degrees Celsius and a 5th generation network as low as 25 degrees Celsius. The 4G and 5G have reduced temperatures so as to reduce losses and allow the use of low temperature heating sources (e.g. solar thermal) and waste heat. 5G provides the primary heat source for decentralized heat pumps, to enable heat pumps also in the city (where air-liquid heat pumps are not seen as solution due to noise of the HPs and to allow a higher efficiency). The heat source can diverse and of varying degrees of sustainability, providing the opportunity to reduce greenhouse gas emissions. Enabling decentralized generation and consumption of heat is a big advantage of such a solution, however larger pipe diameters and higher costs need to be accounted for. New buildings need to be designed to accept a low supply temperature, while the building owners can be obliged to be connected and use DH. Existing buildings should be refurbished energetically when connected to a heat network. The indoor heat exchange system may, for example, have to be replaced, piping relocated or networks with lower temperatures might require a higher level of insulation. Furthermore, a booster heat pump might be necessary for the supply of hot water and if the house is disconnected from the natural gas grid, the traditional cooking stove may have to be replaced by an electric one.

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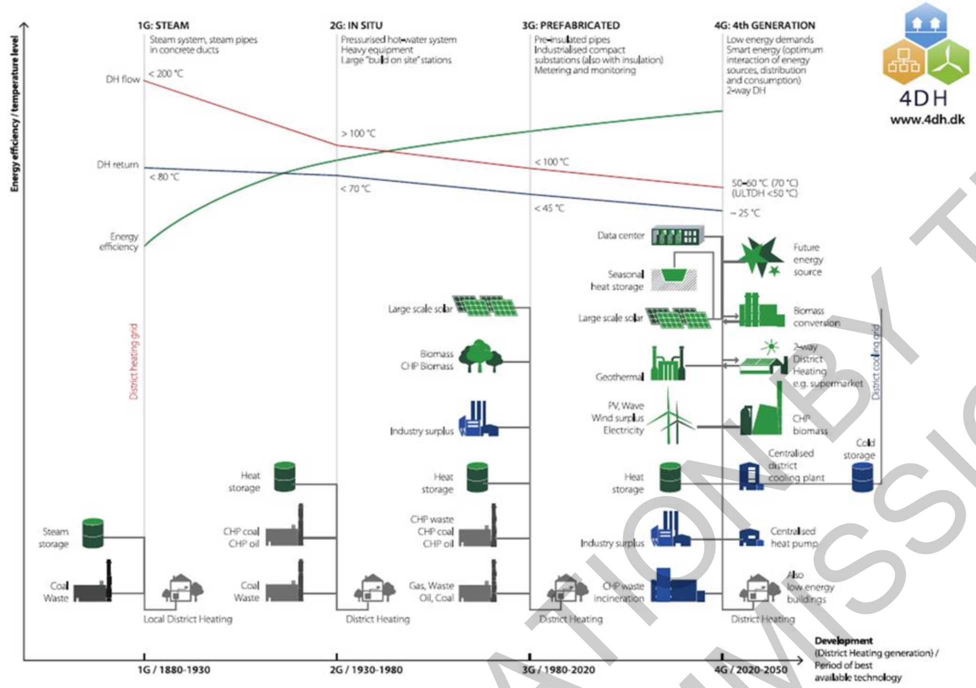
From 3G to 5G District Heating and Cooling networks (generation to substations)	
H. Lund, P.A. Østergaard, T.B. Nielsen et al. *Energy 227 (2021) 120520*  **Fig. 1.** *From the first to the fourth generation of district heating as published in Ref. [5]. Compared to the first version published in Ref. [1], this version includes Ultra-low temperature DH (ULTDH) and certain other features.*	
CO-BENEFITS	The sustainability of the district heat system depends largely on the heat source, but sustainable sources can reduce GHG emissions and improve air quality compared to conventional heating. A small district heating network managed by its users could enhancing citizen participation, connectivity, and community. Certain types of heating systems are also able to provide cooling, reduce hot spots/urban heat islands in the city.
EXTERNAL LINKS	• https://energy.nl/data/heat-networks-high-temperature-non-residential-buildings-district-heating • https://energy.nl/data/low-temperature-heat-networks-district-heating • https://energy.nl/data/large-scale-heat-network-high-temperature-district-heating • https://www.sciencedirect.com/science/article/pii/S0360544221007696 • https://www.sciencedirect.com/science/article/pii/S1364032118308608 • https://adgeo.copernicus.org/articles/49/129/2019/ • https://5gdhc.eu/5gdhc-in-short/ • https://www.thermos-project.eu/project/related-projects/

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3.2.12 Renovation of DH&CN (1G and 2G)

- Authors: **REGEA**
- Knowledge Repository link: **https://netzerocities.app/resource-838**

Renovation of DH&CN (1G and 2G)
District heating and cooling systems consist of **heating and/or cooling production facilities and distribution grids** similar to electricity systems. They essentially produce heating and cooling energy remotely and transport it to the consumers. The sizes, temperatures, and energy supply options within these systems vary greatly across Europe and the World. **The first and second generation of district**

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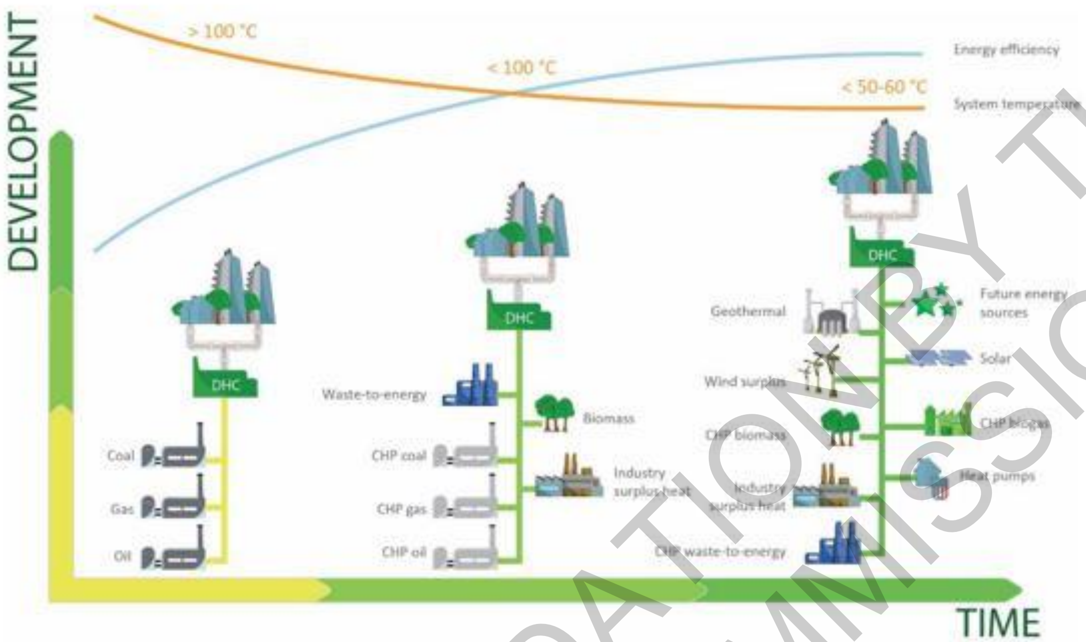
Renovation of DH&CN (1G and 2G)

heating systems usually refer to older and less efficient networks operating at high supply temperatures, above 100°C, and are usually supplied with heat predominantly produced from fossil fuel sources. The working fluid in first-generation district heating systems is steam and in the second generation, it is pressurized water. Cooling is rarely if ever a part of such systems.



Source: Upgrading the performance of district heating networks, Technical and non-technical approaches, Upgrade DH Handbook

Due to the high supply temperatures of these systems, which are usually the result of inefficient buildings which require them, the **options for the utilization of renewable energy sources are limited.**

Because of this, the first step towards the renovation of the district heating system is to **refurbish the buildings.** Once all buildings are refurbished, the district heating can be **adapted by reducing the supply temperature to 60°C**, which allows the **inclusion** of **renewable energy sources** (solar thermal, waste heat) **and heat pumps** as energy sources in the grid.

If not all buildings are refurbished, another possibility is to **reduce the supply temperature** of a part of the district heating system and use the return heat from the traditional part to supply the part of the grid with a lower temperature (cascade use of heat).

CO-BENEFITS	The sustainability of district heating and cooling depends on the sustainability of the energy supply into the system. Compared to individual heating and cooling solutions, district systems have a strong potential to both Reduce GHG emissions and Reduce energy needs. Additionally, the removal of individual building combustion systems will improve air quality and can potentially reduce hot spots/urban heat islands in the city which can be amplified by some technical solutions.
EXAMPLES	• Cityfied project: where the buildings and the district heating network was renovated, to switch from gas-fired boilers to biomass ones, and also substations were added at building level (to control temperature depending on each building and demand), and insulation was added to the DHN https://blog.cartif.es/en/cityfied-project-four-years-of-energy-efficiency-actions/ • Technology Data for Generation of Electricity and District Heating (Danish Energy Agency)

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Renovation of DH&CN (1G and 2G)	
	• Upgrading district heating networks in Europe - Final Project Report (upgrade DH)

Renovation of DH&CN (1G and 2G)	
PRE-CONDITIONS & ENABLING CONDITIONS	DH&CN networks present a high potential for the transition of the heat sector, both technically and organizationally. They allow the integration of renewable energies, to improve the overall energy efficiency, as well as to facilitate sector coupling (coupling between heating, electricity and mobility). Usually, the overall upgrading process to improve the efficiency of DH grids is complex and sophisticated. It is time-consuming, long-lasting and implies high investments. Impacts on the connected buildings must be considered, for example when lowering the operation temperatures. It usually implies a direct cooperation with building owners and end consumers. Such a long and global process also has an impact on the city's or district's life that should not be underrated. That is why the upgrading process should be very carefully planned in the long-term. The goal is to retrofit DH systems, so that they are efficient and that they have zero (or close to zero) emissions and thus, that they contribute to mitigate climate change. Neither globally, nor in Europe, many DH system operators have yet exploited the real opportunities for lower CO2 emissions, which were achieved by the forerunner countries Iceland, Sweden, or Norway (Werner, 2017). In 2016, modest improvements have been achieved by renewable energy sources integration in the DH sector worldwide, where modern renewable energy supplies approximately 9% of total global demand. The timeline and complexity of the implementation of upgrading measures depends on the identified upgrading measures. It can be rather fast and uncomplicated for smaller upgrading measures, long-lasting and sophisticated ore something in between. In any case, a good planning and process is needed. The first phase of an upgrading process aims at creating a solid base for such a process. A good preparation is achieved by starting the organizational process together with concerned stakeholders, by establishing a detailed assessment of the starting situation and by identifying suitable upgrading measures. Some of the activities that are suggested are: • Detailed assessment of the starting situation and technical diagnosis of each demonstration case • Elaboration of a list of potential upgrading measures for each demonstration case that constituted the base of the next phases of the upgrading process • Techno-economic analysis of the upgrading measures and planning of its implementation of upgrading measures • Depending on the individual challenges and the strategy, the demonstration cases can apply different tools
CONSTRAINTS/ BARRIERS for implementation	One of the biggest barriers currently towards the increased share of DH in Europe is the competition of this sector with natural gas. However, DH is also in competition with all other heating options. A heating system which was once chosen, will usually not be changed at short notice. Due to the lack of knowledge of the broad public on DH and the low natural gas prices in some locations, it is not unusual for the new buildings to connect to a natural gas grid rather than the DH grid, despite its availability at the location.
INSTRUMENTS/ Processes for implementation	The potentials for DH are currently very high. In order to achieve a sustainable and decarbonized heating sector, DH should be expanded to cover a much higher share of heat demand. This must be combined with the implementation of energy saving measures in buildings in order to enable the use of low temperature heat produced by various

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Renovation of DH&CN (1G and 2G)	
	renewable sources like solar, geothermal etc. The remaining part of heat demand in low density areas should be covered by individual heat pumps
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	The first and most important aspect for upgrading procedures is the question on the current and future purpose of the energy generation facility. Thus, any upgrading measure should consider the following issues: • **Future changes in the power sector**: Due to climate change and energy policies in Europe, the energy transition is proceeding, and considerable changes are expected in the power sector. • **Efficiency requirements**: The electrical efficiency of fossil power plants is in the range of 30% to 40%. The connection of DH to these plants was often a measure to increase the overall efficiency by using a share of the heat. However, the amount of heat used to increase the overall efficiency depends on the heat demand and on the location of the plant. • **Future heat demand**: The future heat demand of an existing DH system may change. On the one hand, the efficiency status of buildings may increase, thus, requiring less heat, on the other hand, new settlements and districts may be connected to DH.
IMPACTS (Indicators & DNSH)	The improvement of the environmental impacts can be an important target for the upgrading process. Thereby, the motivation for increasing the environmental performance from the company viewpoint can be manifold: • Idealistic motivation: this applies especially to DH cooperatives, public companies, or companies owned by the heat consumers. • Marketing motivation: through a green image of the company, more customers could be gained. • Forced motivation: through mandatory requirements or legislation, companies could be forced to fulfil certain environmental requirements, e.g. obligations on emission reductions. • Economic motivation: improvements on the environmental performance could contribute to the economic benefits, e.g. in the case of cheaper fuels or within the CO_2 emission trade scheme. • The reduction of CO_2 emissions and the improvement of DH system's efficiency are the key elements for most goals on environmental improvements. Thereby, especially improvements on the efficiency have a positive impact on the DH company itself. Efficiency gains due to upgrading measures often imply also economic benefits caused by less fuel consumption or electrical energy savings. The efficiency's improvement is an important driver for the reduction of CO_2 emissions
Additional information from CASE STUDIES	• Integration of Thermal Storage in Existing DH System in the City of Zagreb • Optimisation of Pumping Operations in the DH System of Ferrara • Integration of Tube Collectors for Solar District Heating • Biomass Fired Boiler House at the Plant Salcininkai • Renovation of the DH System in Akmenė • Green Energy Park Livno • Replacement of Fossil Fuels in the DH Sector of Lithuania • Integration of Solar Thermal Energy in an Existing DH System • Energy Renovation with Focus on Low-Temperature DH in Albertslund • Interconnection of Two Separated DH Networks in Italy Source : Upgrade DH handbook, 2019

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This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

3.2.13 Microgrids

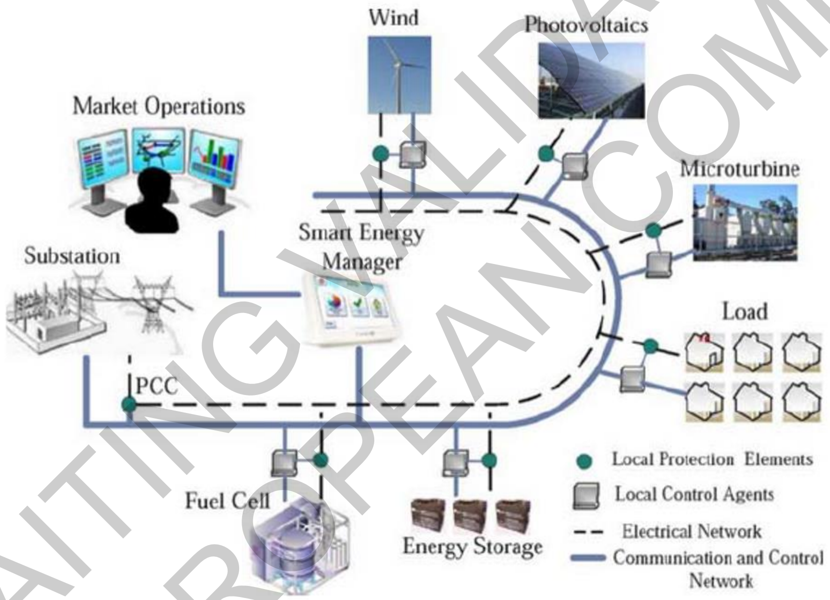
- Authors: **Fraunhofer**
- Knowledge Repository link: https://netzerocities.app/resource-888

Microgrids

Microgrid is usually understood as **sub-area of an electricity distribution network** that is organized and operated **independently** but is **connected to the public electricity grid**. Several energy producers and consumers are connected to the microgrid, whereby its expansion is usually limited to campus, several buildings, or a neighbourhood due to the limitations of the regulatory framework. The microgrid has an intelligent control system and optimizes operation in such a way that the highest possible proportion of self-sufficiency is achieved with local renewable energies and the purchase and feed-in of electricity is designed to be as system-serving as possible for the public grid.

In microgrids, **mostly photovoltaic systems and CHP units** (e.g. with biogas) are used for power generation combined with stationary batteries. Controllable loads are usually heat pumps that use heat or cold storage as a buffer, as well as an e-mobile charging infrastructure that enables controlled charging and discharging of electric vehicles. Demand-side management can be used to tap further flexibility potential.

The advantages of microgrids are the **locally optimised climate-neutral energy supply solution with lower costs for consumers**, as grid charges and other levies are avoided. The possibilities of operating a microgrid coupled to the public electricity grid and the economic advantages that can be achieved depending on the regulatory framework conditions, which differ from country to country.



CO-BENEFITS	Microgrids **reduce GHG emissions** since a climate-neutral energy supply is enabled by the microgrid. The access to **clean and affordable energy** is simplified, and the technological readiness is further increased by micro grids. Furthermore, micro grids support the sharing economy since the prosumers first exchange the generated energy with the other prosumers.
KEYWORDS	Microgrids are a possibility to **develop solutions for neighbourhoods**. The participation of the citizens living in the neighbourhood is necessary. Energy communities could provide an organizational framework to provide microgrids. However, microgrids are also an approach to develop and test new business models (energy sharing on the local level) and could become pilots to implement climate neutral areas which could be then distributed to other areas of the climate neutral cities.

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<table>
<tr><th colspan="2">Microgrids</th></tr>
<tr><td>EXTERNAL LINKS</td><td>
https://microgridknowledge.com/microgrid-defined/
https://www.alpine-space.org/projects/alpgrids/en/home
https://www.delta-ee.com/blog/will-microgrids-become-increasingly-important-in-the-european-energy-sector/
https://www.researchgate.net/publication/270568142_Analysis_of_European_policies_and_incentives_for_microgrids
https://new.siemens.com/global/en/products/energy/energy-automation-and-smart-grid/microgrid.html
https://microgrid-symposiums.org/
</td></tr>
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<table>
<tr><th colspan="2">Microgrids</th></tr>
<tr><td>PRE-CONDITIONS & ENABLING CONDITIONS</td><td>
Micro grids are local grid units to which the end consumers are connected. There is no uniform definition of micro grids. In general, however, two types can be distinguished:

A. Micro grids that are part of the public electricity grid and are subject to its regulation. Within this regulatory framework, local energy markets can be established in the micro grid to a limited extent, for example.
B. Micro grids, which are separated from the public electricity grid by regulation and are not subject to its regulation. This can enable significant cost advantages, but these depend on the specific framework conditions.

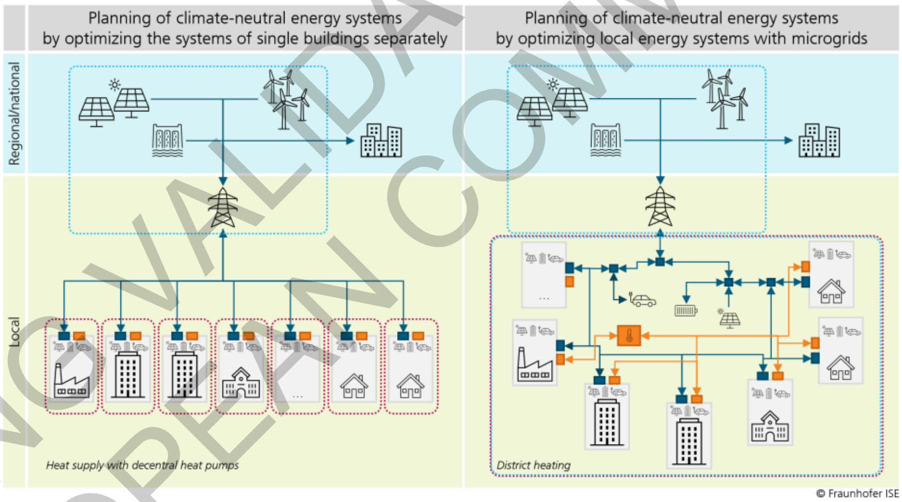

Figure: A microgrid introduces an additional level of operation and optimisation into the energy system at the local level

In the following, microgrids are described that are local grid areas and are operated independently of the public electricity grid, but are connected to the electricity grid (Type B). They require the following prerequisites:

National energy legislation allows microgrids and defines the framework conditions under which they can be operated. In Germany, for example, so-called customer grids are possible, which are not subject to the rules of the regulated energy grid (§ 3 no. 24a EnWG). However, these are only possible within the following limits. Firstly, they must be located in a spatially coherent area. Secondly, they must be connected to an energy supply grid or to a generation plant. Thirdly, they must be insignificant for ensuring effective and undistorted competition in the supply of electricity and gas, and fourthly, they must be made available free of charge and on a non-discriminatory basis to any person, irrespective of the choice of energy supplier, for the purpose of supplying the connected final consumers by means of through-transmission. The limits of these

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Microgrids	
	regulations are not clearly defined. For example, some housing associations have set up microgrids as customer grids for their large residential buildings. A court has ruled that no more than 100 consumers should be connected to the customer grid and no more than 1,000 MWh of electricity should be passed through in order to be insignificant for competition. It is further significant that the requirement of free choice of an energy supplier necessitates detailed accounting of electricity volumes. • **Contractual issues:** if the land on which the microgrid is installed belongs to more than one owner, agreement must be reached on the installation and operation of the microgrid, and appropriate contracts must be concluded. For example, multi-family houses owned by a housing company, where the rented flats are supplied via the microgrid, are well suited. • **A business model** for the operation of the microgrid must be in place that also makes the operation economically advantageous. Whether this is the case depends, among other things, on the energy consumption and the load profiles of the consumers in the microgrid, as well as the possibilities of generating electricity cost-effectively with renewable energies on site and consuming it directly. Furthermore, the necessary administrative and billing costs must not be too high. • **A competent service company** is needed to efficiently organise the operation of the microgrid and its facilities and to professionally handle the administration and billing in accordance with the legal requirements. • **Enabling conditions:** Decisive for the possibilities of implementing independently operating microgrids and their economic and ecological advantages are their framework conditions, which are set by national energy legislation.
CONSTRAINTS/ BARRIERS for implementation	Implementing a microgrid is easiest when developing new neighbourhoods, especially if the site is owned by a developer. The implementation of a microgrid is also possible for larger building ensembles of an owner with many tenants. In many other cases, the organisational and other barriers are relatively large. Important for a successful implementation of a microgrid is a professional planning and examination of the energetic, economic and legal aspects. Appropriate experts must be involved in each case.
INSTRUMENTS/ Processes for implementation	The following steps are necessary to implement a microgrid: • **Development of an energy concept** for the micro grid based on defined goals for the project (e.g. high degree of self-sufficiency with renewable energies, lower energy costs, etc.), evaluation of the possible energy system design and the achievable results. • **Investigation of the business models** taking into account the regulatory framework. For this purpose, a legal expert should be involved who knows the local national regulations for the operation of local electricity grids but also, for example, of local electricity markets and renewable energy communities. Development of an optimised business model taking into account the developed energy concept. 3. • **Conceptual design of the operational implementation** of the microgrid in terms of legal form, organisational structures, definition of stakeholders (owner, organiser, operator, members, consumers, etc.) and technical requirements for implementation. For example, the establishment of a local energy market requires a local trading platform and software for intelligent energy management, which have been developed in recent years in several research projects, including on a blockchain basis. • **Setting up the legal entity, organisational structures and implementation of the micro grid.**
DRAWBACKS/ ADVERSE IMPACTS of the	Measures to increase self-sufficiency in renewable energy and reduce energy costs could be adverse to the surrounding energy system. By organising itself and separating itself organisationally and operationally from the surrounding energy

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Microgrids	
solutions after implementation	system, a microgrid may make it more difficult to find common solutions, e.g. at the neighbourhood or city level, which could be beneficial for the energy transition as a whole. Within the microgrid, there is a risk that business models (e.g. local energy trading) turn out to be not as advantageous in real operation as expected, if e.g. the energy demand is lower than expected, the generation of renewable energy is possible to a lesser extent or is more expensive than expected, the operating and administrative costs are higher than calculated or the regulatory framework changes and expected modes of operation are no longer possible.
IMPACTS (Indicators & DNSH)	Microgrids are a concept to achieve the strengthening of the role of on-site energy supply. The successful implementation of a microgrid can be measured with the following indicators: • **Increased share of renewable energy self-sufficiency:** microgrids aim to harness the use of local renewable energy potential available on-site in the microgrid. This is achieved through the use of electricity and heat storage, sector coupling through the use of electricity for heat supply and mobility needs, the control of loads through controlled charging of electric vehicles or the use of demand side management as well as an intelligent energy management system. In addition, there can be own marketplaces and trading mechanisms. • **Reduced energy costs for connected consumers:** to energy costs of connected consumers can be reduced by using local resources, adapting the energy system to local needs, reducing the transport of energy over long distances and avoiding taxes, fees and charges.
Additional information from CASE STUDIES	Only a few micro grid projects are implemented in Europe yet. • https://pebbles-projekt.de/en/ • https://www.bable-smartcities.eu/explore/solutions/solution/smart-microgrids.html • https://www.researchgate.net/publication/330367382_Design_of_a_Microgrid_Local_Energy_Market_on_a_Blockchain-Based_Information_System • https://www.siemens.com/global/en/company/stories/infrastructure/2020/microgrid-project-in-vienna.html • https://drawdown.org/solutions/microgrids The term Microgrid is rather used in the USA to describe the concept of local grids and markets: • https://www.brooklyn.energy/ • https://mayor.dc.gov/release/mayor-bowser-announces-new-microgrid-st-elizabeths-east-increase-resiliency-and-reliability

3.2.14 Energy management techniques

- Authors: **AIT**
- Knowledge Repository link: **https://netzerocities.app/resource-898**

Energy management techniques
To reach the target of climate neutrality of European cities by 2030, it is very important to introduce renewable energy systems into the global energy system. To **manage the fluctuating power generation of renewable energy systems, it is very important to use energy management techniques.** One of the energy management techniques is to establish energy communities in these cities. e.g. AIT has made in cooperation with Wien Energie a study about energy communities as part of smart and sustainable urban districts. On the basis of the fact that the energy demand is covered by locally available renewable energy sources, energy communities can contribute to grid stability and strengthen the local energy supply security.

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Energy management techniques

As an energy management technique, it is necessary to e**stablish a digital smart network of infrastructure facilities and the flexible handling of data from different actors.** Here is the link to each other in almost real-time importance, so that the energy requirements of all consumers are intelligently estimated and on that basis the generation and supply of energy can be dynamically adapted. Another energy management technique, except the establishment of energy communities, is "Demand Side Management" where based on the grid situation (energy surplus/ energy deficiency), loads can be targeted switched off or on e.g. in the industry. The fundamental base of all the energy management techniques is ICT (Information and communications technology), which is defined as a diverse set of technological tools and resources used to transmit, store, create, share or exchange data and information.

Figure reference: https://communitiesforfuture.org/event/what-makes-energy-communities-the-future-of-the-energy-system-2/

The figure illustrates an example of an energy community. The components of this energy community example are smart homes, smart transport, energy storages, renewable energy sources, the grid management and a distribution network. They are connected by ICT and use energy management techniques (e.g. smart meter, smart network, etc.). Reference: https://communitiesforfuture.org/event/what-makes-energy-communities-the-future-of-the-energy-system-2/

CO-BENEFITS	The co-benefits of energy management techniques are among other things the enhancement of the stability of the urban infrastructure, for example the electrical grid. Especially in energy community, energy management techniques can support the balance of the energy supply and the energy demand by using ICT (Information and communications technology) and using energy from local energy sources. Moreover, energy management techniques ensure because of the use of a digital smart network the increase the access to clean, affordable, and secure energy.
EXTERNAL LINKS	• https://www.energy-community.org/ • https://positionen.wienenergie.at/wp-content/uploads/2021/04/Studie-Energiegemeinschaften.pdf

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Energy management techniques	
PRE-CONDITIONS & ENABLING CONDITIONS	***Climate and geography:*** Energy management techniques are dependant to climate and warming trends, geography due to natural assets, weather conditions (Wind, solar irradiation, …). Balance of the energy supply with the energy demand: If the energy supply is not in balance with the energy demand due, for example, to the high integration of renewable energy sources into the energy system and their dependence on weather conditions (Wind, solar irradiation, …), then energy management techniques are necessary. ***Urban form and layout:*** Urban form has great effects on building-integrated photovoltaic systems and on the integration of renewable technologies and hence on energy management techniques. For example in a less denser urban area, integration of PV is much easier for energy harvesting. ***Technical aspects/infrastructure:*** Energy management systems can leverage several infrastructure systems and technologies to optimize the use of energy resources. Some examples of infrastructure systems that can be used by energy management systems include: • Information and Communication Technology (ICT): ICT infrastructure systems such as sensors, communication networks, and data storage systems can be used by energy management systems to collect and analyse real-time data on energy usage. • Operational Technology (OT): OT infrastructure systems such as supervisory control and data acquisition (SCADA) systems and programmable logic controllers (PLCs) can be used by energy management systems to control and automate energy-related processes and operations. • Big Data Analytics: Big data analytics infrastructure systems can be used by energy management systems to process and analyse large volumes of data from various sources to identify patterns and trends in energy usage and to develop predictive models for energy demand and supply. • Cloud Computing: Cloud computing infrastructure systems can be used by energy management systems to store and process large volumes of data, provide scalable computing resources, and support remote access and collaboration. • Internet of Things (IoT): IoT infrastructure systems such as smart sensors, meters, and devices can be used by energy management systems to collect real-time data on energy usage and to automate and optimize energy-related processes and operations. Overall, the integration of these infrastructure systems and technologies can help energy management systems to optimize the use of energy resources, reduce energy costs, and improve energy efficiency and sustainability. ***Policy and regulatory/legal framework:*** • Energy Management System Standards: Standards such as ISO 50001 provide a framework for establishing, implementing, maintaining, and improving energy management systems. ISO 50001 is considered to be the most important International Standard for improving energy efficiency. Among others, it also supports the United Nations' Sustainable Development Goals (SDG), specifically SDG 7 (affordable and clean energy) and SDG 13 (climate action). • Energy Efficiency Directive (EED) (2011 and 2018): Local public bodies and social housing bodies governed by public law were encouraged to adopt an energy efficiency plan and put in place an energy management system

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Energy management techniques	
	Funding and financing: • Financial Incentives: Governments can offer financial incentives such as tax credits, grants, or low-interest loans to encourage the adoption of energy management systems. • Energy Performance Contracts: Energy performance contracts provide a financing mechanism for energy efficiency improvements by enabling energy savings to pay for the upfront costs of installing energy-efficient equipment or implementing energy management systems. • Emissions Trading Schemes: Emissions trading schemes provide a market-based mechanism for reducing greenhouse gas emissions by allowing companies to trade emissions allowances. ***Economic and social context:*** Project governance and implementation modalities: Energy prices is one of drivers in willing to adopt energy management systems. The higher the prices the stronger are incentive for individuals and industry to integrate energy management systems and reduce energy consumption and hence the costs. Energy security and independency are the impacts which are achieved by energy management systems. Environmental and sustainability concerns can also be a significant driver of energy management system adoption, as companies and individuals seek to reduce their carbon footprint and promote sustainable energy use, which partly go hand in hand with cultural and behaviour of the users.
CONSTRAINTS/ BARRIERS for implementation	• Different constraints and barriers for implementing energy management systems are: • Lack of awareness, resistance to change • Upfront costs • Complexity and requiring reliable techniques • Some regulations, which are complex, outdated or even don't provide sufficient incentives • Lack of accurate, real-time data availability • Privacy policy, especially in the household sector
INSTRUMENTS/ Processes for implementation	• Energy communities • Energy management standards (family of standards are relevant for energy management standards: ISO 50001-50007, 50515, 50047 provide a framework for establishing, implementing, maintaining, and improving energy management systems. • Building energy codes that define the minimum energy efficiency standards for new buildings or renovations • Policy and regulatory frameworks have a great impact • Research and development can have a supportive role for achieving energy efficiency
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	• Upfront and operation costs • Heavy reliance on technology • Data privacy • Energy rebound effect
IMPACTS (Indicators & DNSH)	***ISO 50021:2019*** Energy management and energy savings — General guidelines for selecting energy savings evaluators: This document gives guidelines for selecting energy savings evaluators to determine ex-post (realized) energy savings for projects, organizations, and regions. It gives general principles and identifies the key factors to consider. It also defines roles and responsibilities, recommends the required competence, and

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Energy management techniques	
	provides key elements for assessing the knowledge and skills of energy savings evaluators. At the project and organization level, this document is applicable to both internal and external energy savings evaluators.
Additional information from CASE STUDIES	Practical guide for implementing energy management systems (UNIDO, 2017) A use-case for energy communities with updated German renewables law .

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3.3 Mobility and Transport

- **Knowledge Repository: Mobility and Transport: https://netzerocities.app/resource-2488**

Table 5: Mobility and Transport solutions

Mobility and Transport		Section
Vehicle solutions	Zero emission buses	3.3.1
	Zero emission electric cars	3.3.2
	Hydrogen Fuel Cell Electric Vehicles (FCEVs) in urban transport	3.3.3
	Cooperative, connected and automated mobility (CCAM)	3.3.4
Infrastructure solutions	Bi-directional EV charging (V2X)	3.3.5
	Public charging system for EVs	3.3.6
	Fostering cycling	3.3.7
	Fostering walking	3.3.8
	Mobility hubs	3.3.9
Service solutions	Goods delivery with Drones	3.3.10
	Electrified urban freight delivery/ Last mile delivery	3.3.11
	Fleet decarbonisation	3.3.12
	Car sharing	3.3.13
	Shared micromobility	3.3.14
	Collective passenger transport	3.3.15
	Mobility as a Service (MaaS)	3.3.16
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	Parking policies, management and fees, smart parking	3.3.18
	Smart cards	3.3.19
	Multimodal ticketing and smart cards	3.3.20
	Multimodality	3.3.21

3.3.1 Zero emission buses

- Authors: **EIT-UM**
- Knowledge Repository link: **https://netzerocities.app/resource-398**

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the "orange" fields of this solution, and then it has been afterwards reviewed by JRC and completed the "pink" fields, and the Knowledge Repository content has been updated with JRC's input. So, here only the "orange" fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

Zero emission buses
According to the **Clean Vehicles Directive (CVD)** (EU Directive 2019/11610), a zero-emission bus is a "clean vehicle (…) without an internal combustion engine, or with an internal combustion engine that emits less than 1g CO2/kWh (…) or that emits less than 1g CO2/km".

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Zero emission buses

Stadtwerke Münster – MünsterView / Heiner Witte

Some types of **zero-emission buses**, like trolleybuses, have been in operation for many years in European cities. Others include **battery electric buses (BEB)**, **fuel cell hydrogen electric buses**, **natural gas buses** or buses feed with **biofuels** (e.g. bioethanol or biodiesel, if they are not blended with conventional fossil fuels). BEB have experienced the fastest increase and, according to Interact Analysis, it is expected that in 2025 around 40% of new city buses registered in Europe will be BEB.
Bus fleet electrification combined with the use of renewable energy is an opportunity for cities to make public transport greener and healthier. It has the potential of a significantly higher impact than the electrification of cars since buses have more operating hours per day and a higher annual fuel consumption (ELIPTIC Policy Recommendations, 2018). According to ELIPTIC project, "it takes 100 electric cars to achieve the impacts of one electric bus (but there is not 100 times the funding for electric buses)".

Trolleybus in Castelló de la Plana - Jürgen Lehmann

There are different **charging technologies** available for electric buses (from a manual plug-in connection to automatic connections such as aerial pantographs or ground-based charging systems), as well as different operational stages in which charging can be carried out (charging at the end of the line, overnight depot charging, in-motion charging or even taking energy from the existing tram/subway network).
For cities that want to include clean buses in their public transport system the **European Commission's Clean Bus Europe Platform** offers tailored technical assistance and the opportunity to learn from already implemented clean buses schemes.

CO-BENEFITS	Improving electrification of public transport contributes to decarbonisation of the transport system and helps to **reduce GHG emissions** in cities. Electrification also accounts for the reduction of local pollution by contributing to **improve air quality** and **reduce noise pollution** and vibrations inside the buses, therefore increasing **user comfort**. Furthermore, it **increases technological readiness**.

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Zero emission buses	
KEYWORDS	Zero emission buses are directly linked with integrated EV/e-bikes charging infrastructure, public charging infrastructure for EVs, collective passenger transport, Mobility management, or Hydrogen Fuel Cell Electric Vehicles.
EXTERNAL LINKS	References of the text: • Clean Vehicle Directive: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019L1161&from=EN • ELIPTIC. Policy Recommendations. https://www.eliptic-project.eu/sites/default/files/ELIPTIC%20Policy%20recommendations_FINAL_LowRes.pdf Other sources: • Clean Bus Report: https://cms.uitp.org/wp/wp-content/uploads/2022/04/ASSURED-Clean-Bus-Report-UITP-Final-v2.pdf • Clean Bus Europe Platform: https://cleanbusplatform.eu/about/the-platform • https://www.sustainable-bus.com/news/electric-bus-market-to-reach-a-40-share-in-europe-by-2025/ • https://corporate.enelx.com/en/stories/2022/02/advantages-of-electric-buses • UITP Policy Paper "Impact of electric buses on urban life": The impact of electric buses on urban life | UITP

3.3.2 Zero emission electric cars

- Authors: **EIT-UM**
- Knowledge Repository link: **https://netzerocities.app/resource-408**

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the "orange" fields of this solution, and then it has been afterwards reviewed by JRC and completed the "pink" fields, and the Knowledge Repository content has been updated with JRC's input. So, here only the "orange" fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

Zero emission electric cars
An **Electric Vehicle (EV)** uses electric power instead of an internal combustion engine powered by other fuel types like diesel fuel or gasoline. It has been increasingly recognized that EV may provide an opportunity to reduce global GHG emissions (UN Habitat, 2014) and **increase air quality**, if powered by **renewable energy sources**. The use of second life batteries and improved battery performance may in the future further reduce the need of raw materials and the related environmental impact.

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Zero emission electric cars	
Scharfsinn / Shutterstock.com - *https://www.shutterstock.com/image-photo/charging-modern-electric-cars-new-energy-515877400* However, the adoption of EV depends on several factors and the collaboration from various stakeholders. The main challenges for **electric car (EC)** adoption are high capital costs, the lack of charging infrastructure, the limited model availability (and therefore less competitive purchase cost) and a lack of awareness regarding benefits, functioning, existing incentives, etc. Adoption of EC can become a grid overload risk since it will add further electricity load, requiring new investment in grid infrastructure to meet this increased demand (World Economic Forum, 2022). Some of these challenges can be overcome by using new solutions such as **smart and flexible charging** (schedule charging based on power constraints, price and priority, selling unused power back to the grid), **smart energy management** (improving EV and stationary load management, reducing the risk of grid overload), or **portable electric vehicle chargers** (solving the lack of charging infrastructure in cities). **Cities** can implement different **measures** to speed up EC adoption, including providing free or preferential parking for EC and priority lane access to car-sharing and ride-pooling companies using EC, introducing zero-emission zones, electrifying the municipal vehicle fleets, simplifying administrative processes to build charging points, providing local subsidies for EC purchase or tax write-offs for companies or citizens willing to install charging points.	
CO-BENEFITS	The use of EVs mitigates the dependence of fossil fuels. It can **reduce GHG emissions, noise pollution** and **improve air quality** in cities. EV adoption also brings economic and social benefits since investments from both private and public sector will modernise the car manufacturing industry and create new skilled jobs, therefore also **increasing skill development** and **improving access to job opportunities**.
KEYWORDS	EVs are directly connected to integrated EV/e-bikes charging infrastructure, and public charging infrastructure for EVs.
EXTERNAL LINKS	Reference of the text: • UN Habitat report (2014): https://unhabitat.org/sites/default/files/documents/2019-06/fostering_sustainable_urban_mobility_solutions.pdf?msclkid=187af77ac63f11ec811a6b53dffd3928 Other references: • Charge, Set, Go! (theicct.org): https://theicct.org/wp-content/uploads/2022/03/Agora-Verkehrswende_Charge_Set_Go.pdf • Here's how to accelerate the electric vehicle revolution | World Economic Forum (weforum.org): https://www.weforum.org/agenda/2022/01/the-ev-revolution-obstacles-solutions/ • e-Mobility Toolbox (emobility.tools): https://emobility.tools/thematic/bdc78b56-9cd8-409e-ad62-7fa41e57bb04

3.3.3 Hydrogen Fuel Cell Electric Vehicles (FCEVs) in urban transport

- Authors: **VTT**
- Knowledge Repository link: **https://netzerocities.app/resource-508**

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the “orange” fields of this solution, and then it has been afterwards reviewed by JRC and completed the “pink” fields, and the Knowledge Repository content has been updated with JRC’s input. So, here only the “orange” fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

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Hydrogen Fuel Cell Electric Vehicles (FCEVs) in urban transport

Hydrogen fuel cells (i.e. fuel cells that are fuelled by hydrogen) produce power, heat and water and when produced using renewable electricity – like solar, wind and hydropower –release neither carbon dioxide nor harmful local air pollutants such as nitrogen oxide (NOx), sulphur oxide (SOx) or fine particulate matter (PM2.5) other pollutants into the air.

In the urban transport, **fuel cell electric vehicles (FCEVs)** are complementary to Full Electric Vehicles (**BEV**), allowing a transition to zero emission vehicles today for applications that remain hard to decarbonise due to their operational needs. FCEVs offer **fast refuelling** (3-5 minutes) and long driving range (500km+ on a single tank), which exceed the corresponding characteristics of BEVs. In the urban context, there are two vehicle groups, in which BEVs have challenges and FCEVs show great promise: garbage trucks and taxi fleets.

Garbage trucks on hydrogen are mainly operational in densely populated urban areas, in which there are strict criteria concerning emissions and environmental standards. They are silent and at the same time provide the equivalent flexibility of diesel fuelled vehicles, as battery vehicles struggle to meet the range requirements. The same benefits apply to professional services (such as taxi fleets) and especially to longer trips, e.g. from the city centres to the airports. Also, hydrogen fuel cell buses have been deployed in some European cities.

The development and deployment of a **Hydrogen Refuelling Station** (HRS) **network** is essential to the deployment of Fuel Cell Electric Vehicles.

CO-BENEFITS	Fuel Cell Electric Vehicles improve air quality and reduce noise pollution. Clean and quiet garbage trucks **improve the working conditions** of drivers and loaders and may **improve waste management**.
KEYWORDS	Fuel Cell Electric Vehicles are directly connected to solutions such as Electric cars, Bi-directional EV charging, Public charging system for EVs, Electrified urban freight delivery, Energy Storage solutions, Sustainable fuels, Energy Infrastructure, Green Hydrogen technologies, Smart Energy Management, or Municipal solid waste (MSW).

This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

Hydrogen Fuel Cell Electric Vehicles (FCEVs) in urban transport	
EXTERNAL LINKS	• Hydrogen Mobility in Europe: Emerging conclusions (Technology, Deployment, Benefits, Barriers, Recommendations) • https://www.fuelcellbuses.eu/projects/jive
EXAMPLES	• 15 fuel cell refuse vehicles tested in 8 different cities or regions in Europe: https://h2revive.eu/ • Deployment of 180 FCEVs in Paris, London and Brussels and demonstrations of viable business cases: https://zefer.eu/ • Development and demonstration of 2 garbage trucks on hydrogen: https://www.lifeandgrabhy.eu/ • https://eurocities.eu/latest/city-news-barcelona-to-introduce-spains-first-hydrogen-fuel-cell-busses/
PRE-CONDITIONS & ENABLING CONDITIONS	***Political*** Local and national support is important; Working collaboratively with local authorities and hydrogen stakeholders is required ***Economic*** Funding for market entry (e.g. Incentives, Pilot and Demonstration projects in which the service providers can start the business with FCEVs); Predictability of the total cost (TCO) compared to the traditional, less clean solutions. ***Technical*** Sufficient number of hydrogen refuelling stations/station network. For the first FCEV within a fleet, access to public infrastructure is a necessity, e.g. in industrial hubs (production facilities, port operations). Private refuelling stations can be commercially viable only if vehicle fleets are of a sufficient size to fulfil minimum requirements of hydrogen demand. ***Legal*** A fully integrated regulatory framework that reflects the safety of hydrogen in mobility applications is missing but needed to avoid restrictions to future adoption of the technology; AFIR directive update will require HRS network along TEN-T.
CONSTRAINTS/ BARRIERS for implementation	***Political*** Lack of long-term hydrogen policy and plannability. ***Economic*** FCEVs are still more expensive than conventional vehicles; High investment costs and risks for HRS operators and green hydrogen producers; Uncertainty about hydrogen cost development; Uncertainty about 2nd life vehicle market and value. ***Social*** Vehicles are very silent, which requires extra alert from the drivers and other road users. ***Technical*** Limited supplier diversity; Small number of vehicle models available to fit for the specific purposes of (taxi) operators; In a very hilly area, the trucks can be underpowered. ***Legal*** Regulation only partly ready, e.g. fast refuelling standardization under preparation; No EU/National directives to stall, maintain and repair hydrogen vehicles; Lack of standardization for Heavy Duty applications.

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3.3.4 Cooperative, connected and automated mobility (CCAM)

- Authors: **Rupprecht**
- Knowledge Repository link: **https://netzerocities.app/resource-418**

Cooperative, connected and automated mobility (CCAM)
Cooperative, Connected and Automated Mobility (CCAM) refers to the exploitation of automated driving functionalities and connectivity capabilities towards the establishment of a cooperative and integrated transport system. In this way, CCAM is expected to transform the way we travel and has the potential to **increase traffic safety and performance**, reduce environmental impacts, and enhance the inclusiveness and resilience of mobility services. Through the **synchronisation of traffic and public transport**, and smoothing of the traffic flow, CCAM could significantly increase the service capacity of road infrastructure, and reduce congestion. Besides, new CCAM-enabled mobility services can provide accessible mobility to vulnerable user groups, including disabled people or the elderly. Still, an uncontrolled deployment of CCAM could worsen problems like congestion, pollution and GHG emissions, or urban sprawl.  The envisaged benefits that CCAM might bring can only be fulfilled when local authorities become ‘automation-ready’, i.e. have the capability of making structured and informed decisions to shape CCAM deployment to societal needs. Proactive planning approaches are required to ensure a positive roll-out of CCAM and its alignment with local policy goals. This begins with **planning**, as early as possible, how the introduction of **connected and autonomous vehicles (CAVs)** should unfold, to minimise the potential negative impacts and more importantly make the most of the opportunity to influence the paradigm shift to a more sustainable urban mobility vision.

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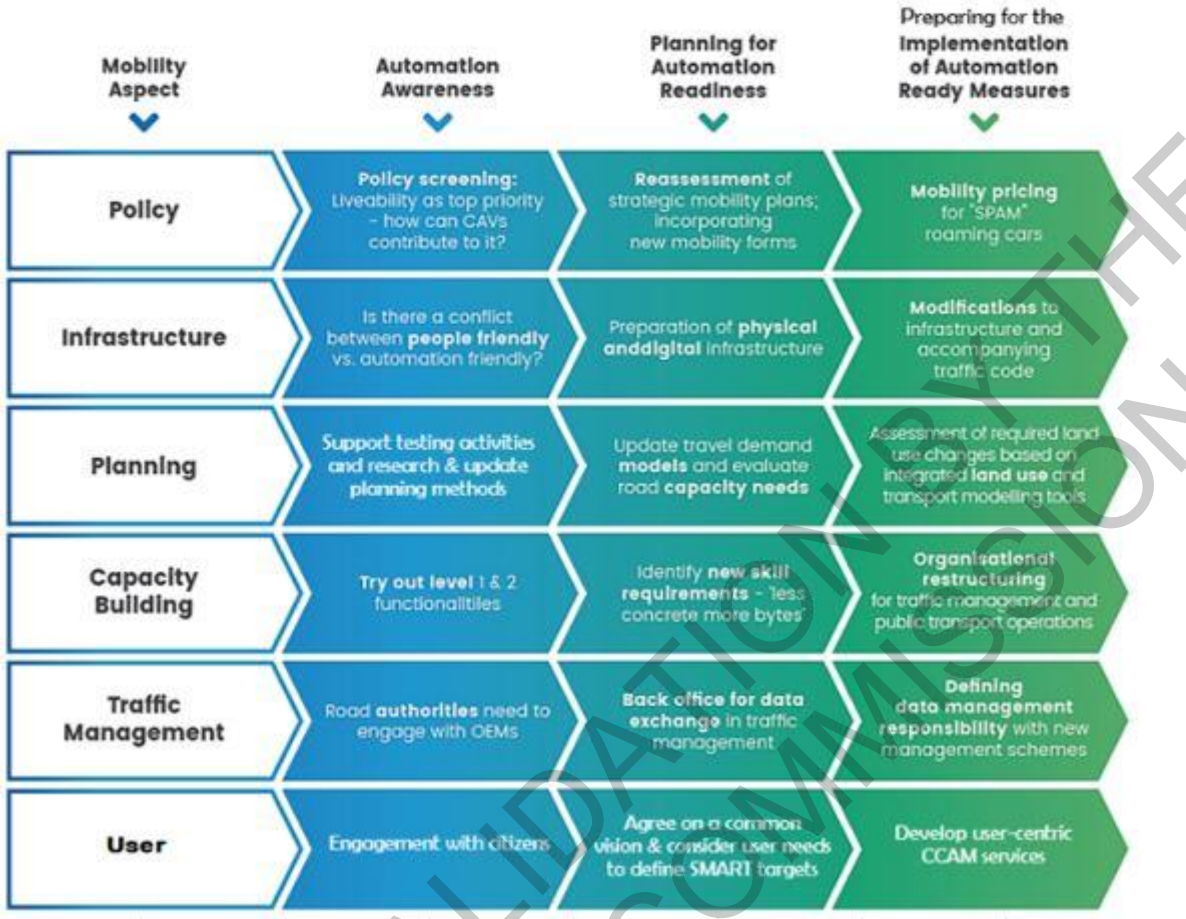
Cooperative, connected and automated mobility (CCAM)



Overview of three phases towards automation-readiness with examples of measures. Source: https://elib.dlr.de/133726/1/TRA2020_Cooperative%20Automated%20Driving%20at%20Transition%20Areas%20v2.pdf

CO-BENEFITS	CCAM has the potential to fundamentally shift the mobility paradigm into a more sustainable urban transport vision, enhancing shared and public services, and in this way **reducing noise and air pollution**, **GHG emissions and energy needs.** Innovative CCAM-enabled shared mobility services, and their cooperative integration with public transport can increase **social cohesion and inclusion**, providing accessible mobility to vulnerable road users and minority groups. CCAM can **reduce road danger** by avoiding human error and exploiting the capabilities of advanced traffic management and communication to detect and mitigate dangerous incidents. CCAM is expected to contribute to the creation of a profitable future mobility industry and maintain relevance as a global export industry, thus **increasing employment rate and jobs**.
EXTERNAL LINKS	• https://www.connectedautomateddriving.eu • https://www.ccam.eu • https://www.eltis.org/sites/default/files/road_vehicle_automation_in_sustainable_urban_mobility_planning_0.pdf • https://www.ertrac.org/uploads/documentsearch/id82/ERTRAC%20CCAM%20Roadmap

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Cooperative, connected and automated mobility (CCAM)	
PRE-CONDITIONS & ENABLING CONDITIONS	***Technical aspects:*** The infrastructure of the city should be well equipped digitally to support CAM functionalities and should be modified with signs and signalling options to incorporate CAVs into the existing traffic fleet. In case of major road intersections or motorway intersections, the facility should be equipped with manoeuvring of CCAM vehicles. ***Policy and regulatory/legal framework:*** The regulatory framework of the city with regards to transport infrastructure should be modified or advanced incorporating CCAM impacts and evaluations to facilitate a smooth transition of the service. Clear goals should be laid down on the basis of national or regional objectives. Data policy should be taken care of because CCAM services involve access and sharing of data. ***Funding and financing:*** Investment in CCAM services or incorporating CAVs into the existing transport infrastructure requires resources and funding as thorough understanding of the CCAM functionalities with the modification of the infrastructure is a pre-requisite to its implementation. ***Economic and social context:*** The introduction of CCAM functionality into the existing infrastructure could lead to a considerable amount of expenditure for the public/private authorities, so detailed study and research of CCAM should be undertaken before venturing into its implementation. Informing the citizens and equipping them with the capacity to claim and exercise their rights and freedoms in relationship to AI in the context of CAVs. Social campaigns and pilot projects should be undertaken to make the citizens more aware of the technical aspects, security and comfort of CAVs causing more social acceptance leading to a better implementation of the service. Investigating the cognitive and technical challenges users face in CAV interactions and the tools to help them surmount these changes. ***Project governance:*** Private and public stakeholders should be collectively involved in implementing the services and sharing knowledge and skills should be guaranteed. Simultaneously citizen engagement through proper awareness and co-creation initiatives should be regularly executed so that CCAM services can function.
CONSTRAINTS/ BARRIERS for implementation	Implementation of automated vehicles would require preparatory action in the fields of transportation planning, traffic control, road infrastructure, urban planning, citizen participation, test fields and data standards and requirements. The social understanding, acceptance, and approval of the new forms of mobility amongst various citizen groups and stakeholders in the urban area are key factors in the CCAM deployment. For conventional road infrastructure, automated recognition of road geometry and signs is important, and the maintenance of this crucial. as of yet there are no norm or standards in the EU referring to traffic sign machine readability. The road infrastructure needs to be adapted in order to facilitate proper functioning of automated vehicle systems. During the initial phase of CCAM implementation, human driving and decisions together with computational capability of CCAM vehicles could lead to more gaps in between them on a particular road network leading to a disruptive traffic facility. Internet and data connectivity of the city/area has to be strong enough to sustain CCAM functionalities to maintain the communication between vehicles and the infrastructure.
INSTRUMENTS/ Processes for implementation	***Traffic parameters and efficiency:*** • Traffic homogeneity: More penetration of CAVs during the course of time would lead to lesser gaps between the vehicles, uniform speed distribution,

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Cooperative, connected and automated mobility (CCAM)	
	efficient lane changing, distributed acceleration and deceleration. These could lead to a uniform and homogenised traffic infrastructure. • Decrease in congestion delays: Enhanced free flow capacity and decreased capacity drops (i.e. fewer episodes of reduced queue discharge rate) could increase the road capacity and thus reduce congestion delays. • Increase in traffic capacity: Automated vehicles could have a positive influence on free flow capacity, the distribution of vehicles across lanes and traffic flow stability by providing recommendations (or even determining in level 3 or higher levels of automation) about time gaps, speed and lane changes. • Travel comfort, Travel safety. Reliability, Performing activities while driving: These functionalities of CCAM are also worth mentioning because due to the fact that travel comfort due to less deviations and fluctuations would increase manifolds. Also, security would be enhanced as communication is possible not only between cars but also between infrastructure, bikers and pedestrians. ***Traffic management:*** Better communication between vehicles and infrastructure could lead to traffic optimization avoiding congestion and delays. Also planned events like football matches or unplanned events (heavy rains), traffic congestion could be avoided. ***SUMP:*** CCAM could act as a tool to satisfy the mobility needs of people and businesses in the cities and their surroundings. It could be integrated into transport modes covering the gaps existing in the present infrastructure like making public transport more efficient and reachable, reducing the load of private cars as car and ride sharing could be more enhanced. Last mile services could also be enhanced for vulnerable road users and also for people living in the outskirts of the city who could then use the public transport more often. With more travel security, lanes for bikes and pedestrians could be developed encouraging more people to undertake these active modes. ***Reduction in costs:*** Generalised costs would like to decrease due to lower effort time and money needed to travel. enhanced efficiency of traffic flow along with more fuel-efficient vehicles because of their lighter design (owing to less risk of having an accident) could also reduce the monetary cost of travel. ***Land Use Change:*** A reduction of off-street parking requirements could bring changes in land use (infill residential or commercial development) and in building design (i.e. access lanes, landscaping). Moreover, surface parking lots and multi-story parking garages in central areas could be significantly reduced, enhancing infill development potential for people-friendly land use. ***Environment:*** Environmental benefits of shared automated vehicles could be very important in all of the pollutant indicators examined (i.e. SO2, CO, NOx, Volatile organic compounds [VOC] PM10, and GHG [Greenhouse gas]) as drastic reduction is forecasted together with ride and car sharing and public transport infrastructure. ***Capacity building and education campaign:*** Ensuring the development and deployment of methods for communication of information to all stakeholders, facilitating training, AI literacy, as well as wider public deliberation. Strategy for capacity building with Stakeholders utilising proper resources and undertaking trainings are instruments for CCAM implementation. Identifying barriers and advantages of CCAM could lead to better understanding of

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<table>
<tr><th colspan="2">Cooperative, connected and automated mobility (CCAM)</th></tr>
<tr><td></td><td>the same and a better evaluation of its incorporation into the system could be performed.

Gender diversity in urban mobility:
Care should be taken to make sure that security of citizens especially women travelling during the night time using CAVs without drivers could be enhanced. Women should be encouraged to use the service through pilot projects, providing the necessary security during the night time.</td></tr>
<tr><td>DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation</td><td>Traffic efficiency and management:
Increased vehicle travel demand could have a negative impact on road capacity owing to more congestion delays and subsequently increased capacity drops.
The use of high capacity public transport systems, such as trains, metro, and light rail might also drop after the introduction of automated vehicles, if ride-sharing or vehicle-sharing could adequately serve high-demand corridors.
The increase of ride-sharing and vehicle-sharing systems might negatively influence the use of active modes, since automated shared vehicles could effectively serve short distance trips or feeder trips to public transportation.
The possibility of increased modal shift from public transport to automated vehicles especially when these vehicles become widely available to travellers with lower value of time.

Vulnerability to cyber-attacks:
Data sharing and security: connected cars require that every vehicle's location and journey history be recorded and saved, but the current level of IT security cannot guarantee that data might be accessed by unwanted third parties.

Costs:
The costs of operating CAVs are highly uncertain. The fixed costs of automated vehicles will be likely to be higher than for conventional vehicles due to the advanced hardware and software technology involved. So, authorities may have to incur excessive cost after implementation the new service and maintaining it. The increased fixed cost could influence the penetration rate and subsequently the magnitude of the effects of automated vehicles.

Changes in employment:
As penetration of CCAM vehicles increases, unemployment could be a massive factor as services of people as drivers, etc. won't be a requirement in areas like public transport or shuttle services.
Vehicle ownership: Increase in the ownership of private vehicles could be on the increase as more people may be prone to buy cars without having to drive them.

City regulations:
City goals are not always directly aligned with other stakeholders' ones, seeking to push automated vehicle technology. After implementation of the vehicles, more efforts are required to maintain the infrastructure with proper efficiency of CCAV in order to fully utilise the advantages of the new innovative system.</td></tr>
<tr><td>IMPACTS (Indicators & DNSH)</td><td>Increase in traffic demand due to more vehicles in the network could lead to unprecedented traffic delays and congestion.</td></tr>
<tr><td>Additional information from CASE STUDIES</td><td>• Autonomous shuttle piloted in Helsinki to deliver proof-of-concept for the management of autonomous public transport fleets | Mobility Innovation Marketplace (eiturbanmobility.eu)</td></tr>
</table>

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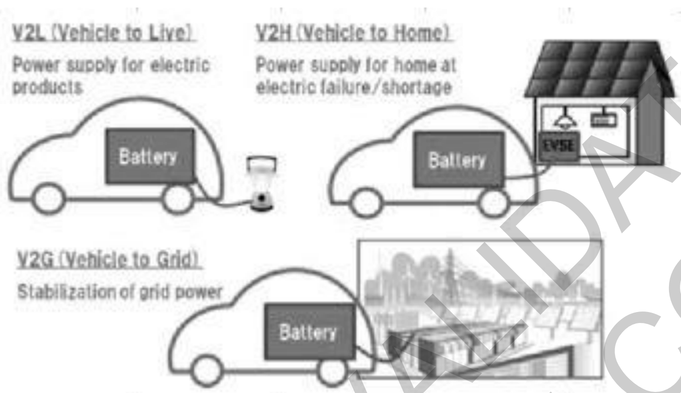
3.3.5 Bi-directional EV charging (V2X)

- Authors: **VTT**
- Knowledge Repository link: https://netzerocities.app/resource-428

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the "orange" fields of this solution, and then it has been afterwards reviewed by JRC and completed the "pink" fields, and the Knowledge Repository content has been updated with JRC's input. So, here only the "orange" fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

Bi-directional EV charging (V2X)

Vehicle-to-everything (V2X) is a technology that enables bidirectional charging possibility between vehicle battery to many different use cases such as homes, buildings, services, factories, power grids, or even another vehicle. V2X is often considered as a solution for **emergency power supply** in the event of a power outage or, especially in case of **vehicle-to-grid (V2G)** for inevitable grid problems when the peak energy demand is higher than the supply capacity of the grid.



V2L (Vehicle to Live), V2H (Vehicle to Home) and V2G (Vehicle to Grid). Source: https://global-sei.com/technology/tr/bn79/pdf/79-08.pdf

V2X not only helps the consumers to save their electricity bill but also supports mitigating climate change and **scaling up renewable energy** by increasing the backup capacity and balancing between energy demand and consumption. Fleet electric vehicles with centralised charging depots can potentially benefit the most from V2X technology. To give an example, the vehicles can be charged during midday hours when solar output is at the highest, or during night when the price of electricity is at the lowest, and then return the power back to grid during evening when electricity consumption peak. V2X technology is currently being used mainly on passenger vehicles but also being investigated for its potential in B2B applications in buses and trucks.

V2X requires vehicle with **discharge functionality**, **bidirectional charger**, communications link between the charger and the vehicle using a V2G-compliant communications protocols ISO 15118 and OCPP 2.0.1, and smart charging control system that supports V2G charger.

Currently, V2X technology has been tested in few pilots around the world. One of the reasons that this technology has not rolled-out yet is that to this date only few BEV support bi-directional charging.

CO-BENEFITS	V2X technology optimises the consumption of electricity and promotes cost-efficient integration of renewable energies and cost-efficient decarbonisation of mobility sector, which in return results in **sharing economy**, **reducing energy needs** and **GHG emissions**, and **improving air quality**. Furthermore, it **enhances citizen participation, connectivity, and community** and **raises awareness/behavioural change**, by allowing citizens to participate in purchasing and selling electricity.

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Bi-directional EV charging (V2X)	
KEYWORDS	V2X is directly connected with other mobility and transport solutions: vehicle solutions, service solutions and mobility management. It is also connected with Integrated Renewable Energy Sources (RES), Integrated Energy Storage, EV charging infrastructure integration, Smart solutions, power generation, storage solutions, sustainable fuels, as well as reduction of pollution to air, water and ecosystems (DNSH); Energy Efficiency measures, Energy social structure, Energy policy and planning support.
EXTERNAL LINKS	• All Nissan Leafs on the market can be discharged with vehicle-to-grid stations: https://www.nissan.co.uk/range/electric-cars-technology/v2g.html
EXAMPLES	• In Switzerland, seven companies launch field trial for bidirectional charging • City-zen smart grid solutions in Amsterdam • Vehicle-to-Everything (V2X) in the Netherlands

3.3.6 Public charging system for EVs

- Authors: **VTT**
- Knowledge Repository link: **https://netzerocities.app/resource-448**

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the “orange” fields of this solution, and then it has been afterwards reviewed by JRC and completed the “pink” fields, and the Knowledge Repository content has been updated with JRC’s input. So, here only the “orange” fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

Public charging system for EVs
Easy access to **public charging for EVs** (including taxis, city utility vehicles, private cars, etc.) is a necessity in transition toward **zero-emission electric transport**. An expanded charging network needs to be user-centred and integrated with public space design, to encourage consumers to move to EVs and increase electric vehicle drivers’ confidence and their practical traveling range. The **charging infrastructures** can be provided in various locations & forms, i.e. on-street charging infrastructure for residents & (fast) charging hubs. However, **interoperability** between the infrastructure and vehicles and smart and intelligent charging should be considered as requirements for public charging to avoid vendor lock-ins & reduce the burden on the grid.  *Electric vehicle charging guide for cities. Source: https://theicct.org/sites/default/files/publications/EV_charging_guide_03162020.pdf* To support the growth of EVs and to fulfil the increasing need for public charging infrastructure, cities need **more public charging points** that are planned according to their unique charging needs. A city’s

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Public charging system for EVs

charging needs could be assessed according to different factors. For example, the required charging power should be assessed based on commuting patterns, vehicle mix, electric vehicle growth expectations, and the electrical grid. Based on **charging needs assessment** the city can on a periodic basis identify the need of charging infrastructure to **meet and sustain EV demand** and develop EV charging deployment involving key stakeholders with an idea to integrate public charging in city's existing and new infrastructure.

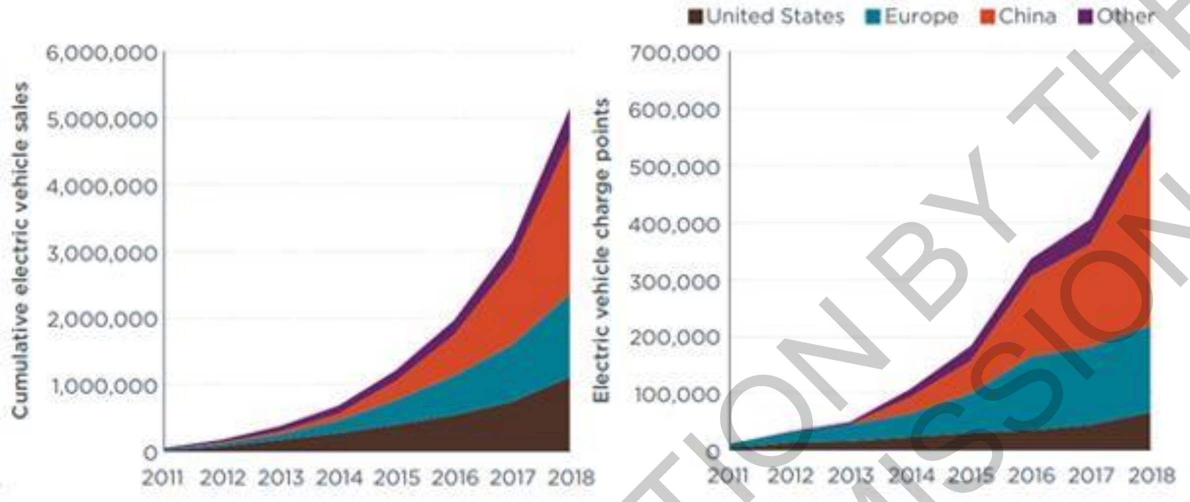

Figure 1. Global electric vehicles and public electric vehicle charging points.

The state of EV charging infrastructure in Europe by 2030. Source: https://www.virta.global/blog/ev-charging-infrastructure-development-statistics#:~:text=On%20average%20in%202021%2C%20the,current%20and%20future%20EV%20drivers

Cities' policy and regulatory tools play an important role to accelerate the pace of charging deployments. These include electric vehicle-ready building codes to reduce future costs; streamlined permitting processes and pre-approval of sites to draw private investment; targeted, easy-to-access incentives to fill difficult-to-reach segments; policies to encourage the electrification of ride-hailing and private-hire vehicles to encourage high-utilization business cases; and working closely with electric utilities and grid operators to reduce stress on the grid (link).

CO-BENEFITS	Public charging system for EVs facilitates the transition towards zero emission transportation, which results in **improving air quality** and **reducing noise pollution**. It also promotes the use of green/renewable energy and therefore **increase access to clean, affordable, and secure energy**.
KEYWORDS	It is directly connected with other Mobility and Transport solutions: Vehicle solutions, Infrastructure solutions, Service solutions, Planning and regulation; Information provision, and capacity building. It is also connected with Integrated Energy Storage, EV charging infrastructure integration, Smart solutions, Integrated urban planning methodologies; Integrated Energy and GHGs scenario and mapping tools, modelling approach; Observatories at EU level, Grants and subsidies, Loans, Key regulation at EU level; as well as with Power generation, Storage solutions, Sustainable fuels, Infrastructure, Reduction of pollution to air, water, and ecosystems (DNSH), Energy efficiency measures, Energy social structure, Replication support, Energy policy and planning support, Business models and exploitation of energy systems, Funds and incentives.
EXTERNAL LINKS	• Start with smart: Promising practices for integrating electric vehicles into the grid • Electrification in sustainable urban mobility planning
EXAMPLES	• Cost-efficient charging infrastructure in existing built-up urban areas

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Public charging system for EVs	
	• [Implementation of fast electric vehicle chargers and an electrified public vehicle fleet in Las Palmas de Gran Canaria | Mobility Innovation Marketplace (eiturbanmobility.eu)]

3.3.7 Fostering cycling

- Authors: **Rupprecht, EIT-UM**
- Knowledge Repository link: **https://netzerocities.app/resource-468**

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the “orange” fields of this solution, and then it has been afterwards reviewed by JRC and completed the “pink” fields, and the Knowledge Repository content has been updated with JRC’s input. So, here only the “orange” fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

Fostering cycling

Cycling has recently become more popular (and is being taken more seriously) as a sustainable urban mobility solution. Cycling is at least part of the solution to multiple urban problems. Cycling can reduce the number of serious injuries and traffic deaths, reduce energy consumption, make efficient and equitable use of space, improve personal health, support local economies and improve social inclusion. It also reduces noise pollution and increases the freedom and independence of children (and of their parents).

Cycling has large potential to **replace car journeys** up to 5-8 km in urban areas. For journeys up to 15 km, for cities with hills and for cities with high temperatures, pedelecs (bicycles that provide electric support while pedalling) are an option. Cycling (whether electrically supported or not) also offers **more flexibility** than public transport for trip chaining (a practice more common for women than men).

To **make cycling a mainstream mobility option**, a transformation of the current road system is needed to create a network of cycle routes that is safe and inviting for those who do not yet cycle. This will require the **reallocation of space from car facilities** (parking, traffic lane) to cycling, the reduction of speeds, the limiting of motorised traffic and the creation of more secure parking facilities for bicycles.

Another area of great potential is the use of **cargo bikes** (or a bike with a trailer), both for private use to transport children or bulky items or in large-scale use for last-mile urban logistics.

There is also potential to increase **social inclusion** by enabling more people cycling (older people or those with physical disabilities) and to encourage people to cycle more (e.g. winter cycling).

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Fostering cycling	
CO-BENEFITS	Reduction of energy needs, **reduction of GHG emissions**, **reduction of road danger**, boost local business, proximity economy, improve air quality and **reduce noise pollution** (assuming less driving), **healthier and more attractive lifestyles**, better physical activity of individuals, enhance attractiveness of the cities, reduce ecological footprint.
KEYWORDS	Cycling promotion is directly connected to solutions such as Mobility hubs, Shared micromobility, Multimodality, Land use planning and urban space management, Fostering walking, SUMPS, or Low emission zones.
EXTERNAL LINKS	• https://cyclingwithoutage.org/ • https://bikemunk.com/cycling-ageing/ • https://wheelsforwellbeing.org.uk/wp-content/uploads/2019/06/FINAL.pdf • https://www.youtube.com/watch?v=X6EaJ1Zd8Kk
EXAMPLES	• Behavioural change campaign encouraging use of the cycle highway between Arnhem-Nijmegen | Mobility Innovation Marketplace (eiturbanmobility.eu) • First bicycle tram offered exclusively to bike users in Konya | Mobility Innovation Marketplace (eiturbanmobility.eu)

3.3.8 Fostering walking

- Authors: **Rupprecht, EIT-UM**
- Knowledge Repository link: **https://netzerocities.app/resource-478**

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the “orange” fields of this solution, and then it has been afterwards reviewed by JRC and completed the “pink” fields, and the Knowledge Repository content has been updated with JRC’s input. So, here only the “orange” fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

Fostering walking
Walking is the most basic, **democratic and space-efficient form of transport** and is open to people of all age groups and socio-economic circumstances. As a mode of transport (as opposed to walking for leisure), walking needs to be considered both as the beginning and end of every trip by any other mode and as a mode of transport itself for short distances. As the first and last mile option for trips made by other modes, it needs to be taken into consideration in **planning**. This includes safe and barrier-free public transport stops and stations with good walking access adapted to all ability levels, as well as escalators and elevators for those who cannot manage stairs. In addition, walking must be taken seriously as a mode of transport in itself, with appropriate and equitable amounts of space allocated to it and infrastructure that is safe and attractive for users of all ages, genders and abilities.

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Fostering walking

A **walkable city** requires consideration at different levels:

1. **at the city-wide level**: pedestrian axes, reduction of urban cuts, hierarchies of road;
2. **at the neighbourhood level**: traffic calming, parking management, reduction of motor vehicle through traffic;
3. **at the street/square level**: allocation of public space, reduction of speed, access for people with reduced mobility, quality and safety of sidewalks and intersections, comfort (shade, benches, water points, clean and accessible toilets).

Walking interventions can include: exploratory walks, tactical urbanism and living labs, citizen involvement in the design and management of public spaces (co-constructed street furniture), temporary or small-scale measures (temporary car-free areas in front of schools, tourist streets, seasonal furniture and parklets), narrowed crossings (widened sidewalks, kerb bulges, mid-crossing refuge islands).

CO-BENEFITS	**Reduce GHG emissions**, reduce energy needs, boost local business (km 0), proximity economy, **social cohesion** (gender, minority groups), **social capacity building**, connectivity, and community, improve air quality, reduce noise pollution, reduce hot spots/urban heat islands in the city, reduction of road danger, **enhance attractiveness of the cities, healthier and more attractive lifestyles**, better physical activity of individuals, better access to living areas for all, **road safety** (Vision Zero), economic development, **tourism** development, improvement of **public health** (fight against obesity, against the loss of autonomy of the elderly, etc.), best place for children and the elderly in the city, optimization of public transport networks.
KEYWORDS	Walking promotion is directly connected with solutions such as Fostering cycling, Mobility hubs, Shared micromobility, Multimodality, Land use planning and urban space management, SUMPs, or Low emission zones.
EXTERNAL LINKS	• https://walk21.com/ • https://www.pedestrians-int.org/en/ • https://www.itf-oecd.org/sites/default/files/docs/streets-fit-allocating-space-better-cities.pdf • https://www.sustrans.org.uk/our-blog/research/all-themes/all/walking-for-everyone/ • https://www.citiesforum.org/news/15-minute-city/ • http://www.bcnecologia.net/en/conceptual-model/superblocks
EXAMPLES	• Bologna's Bella Mossa app provided incentives for citizens to travel more sustainably in the city | Mobility Innovation Marketplace (eiturbanmobility.eu) • Graz implements 'School Living Labs' to provide safer streets for children | Mobility Innovation Marketplace (eiturbanmobility.eu) • Innovative light-up pedestrian crossings implemented in Funchal | Mobility Innovation Marketplace (eiturbanmobility.eu)

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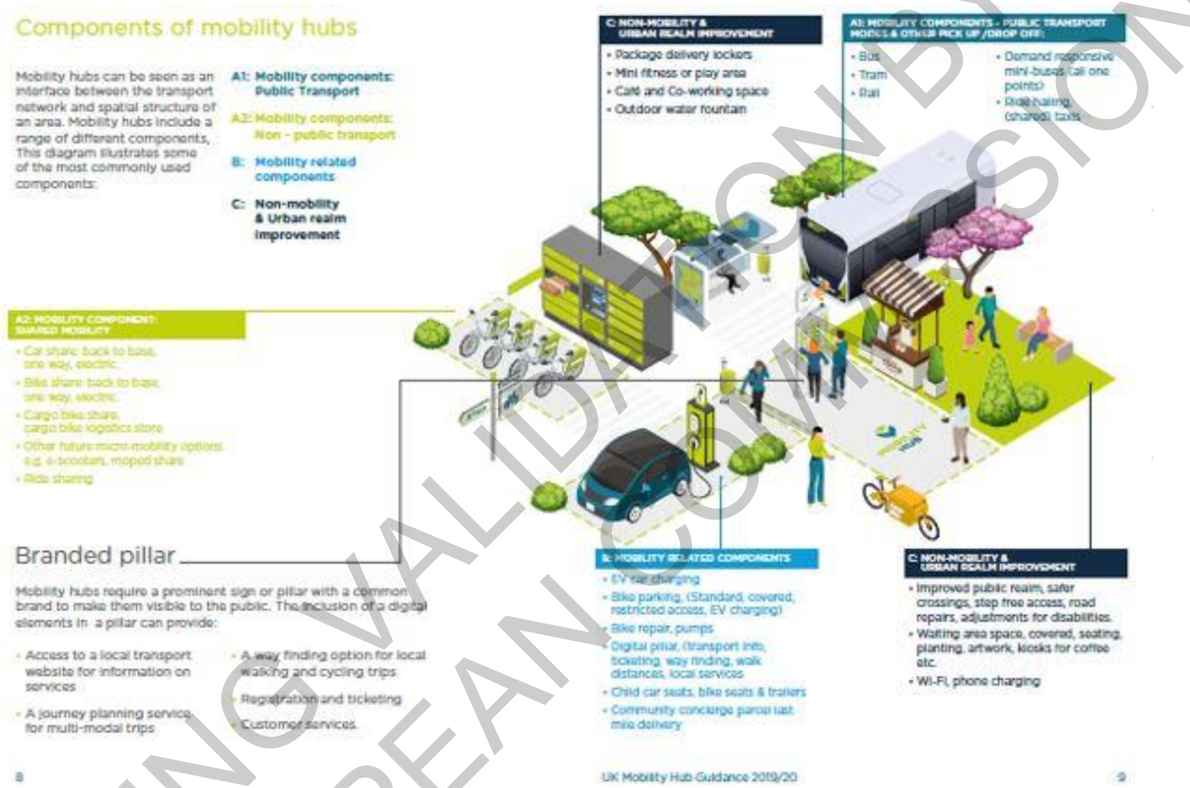
This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

3.3.9 Mobility hubs

- Authors: **UITP**

- Knowledge Repository link: https://netzerocities.app/resource-488

Mobility hubs
Mobility hubs provide a focal point in the transport network that seamlessly **integrates different modes of transport**, multi-modal supportive infrastructure, and turn spaces into places. It is designed and **spatially organised** in a way to facilitate **access to transport modes** and easy transfer between the modes, from rail, to buses, shared cars, shared bikes, and/or shared e-scooters, ride-hailing/shared taxis. Mobility hubs increase the inherent value of every single transport mode connected to the hub. As a result, sustainable transport services are viewed as attractive travel options, as an alternative to private car use.



Components of mobility hubs. Source: https://como.org.uk/wp-content/uploads/2019/10/Mobility-Hub-Guide-241019-final.pdf

Mobility hubs provide as well **different sort of facilities** such as shopping and catering facilities, delivery or pick-up points, bike repair points etc. The more activities are in a hub, the better as it creates a sense of place. Mobility hubs should be **planned** with public transport as backbone. They can be distributed throughout urban, suburban and rural areas to enable access to sustainable transport options to fit individual users' needs.

There are different **types of mobility hubs** based on **scale**:

- **Large urban mobility hubs**: large interchange hubs or city hubs such as central train stations and public transport interchanges, generally located in dense urban areas, with high passenger numbers.
- **Smaller urban mobility hubs**: interchange hubs or linking hubs, linking residents/businesses in surrounding areas to core network service.
- **Suburban Mobility hubs**: linking suburban areas with core centres and core network services. They are usually located in lower density areas where private car ownership and use is higher.

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Mobility hubs	
• **Smaller or rural proximity hubs**: in towns and villages where private car ownership and use is high. Mobility hubs need to be **adapted** to the setting in terms of **purpose and scale**, for instance, rail hubs will offer more space for public transport and bikes (shared or not), shopping facilities etc. while small proximity hubs will offer on top of public transport provision greater choices of flexible mobility (shared cars, shared-bikes/e-scooters, bike parks etc.). Additionally, from an energy point of view, Mobility hubs can include also energy generation (e.g. from solar cells) and electric vehicle charging stations.	
CO-BENEFITS	Mobility hubs encourage the **shift to sustainable transport modes** and active mobility, they participate in Improved public realm through the reorganisation of space around active mobility, around quieter, creating a more pleasant urban realm. They supports **densification** and boost economic activity. They also enhance **attractiveness of the city** thanks to a **better connectivity of mobility services**. They also **boost local business** and favour proximity and sharing economy.
EXTERNAL LINKS	• https://como.org.uk/wp-content/uploads/2019/10/Mobility-Hub-Guide-241019-final.pdf • https://www.arup.com/perspectives/publications/research/section/future-mobility-hubs • https://www.afd.fr/en/ressources/multimodal-transport-hubs-good-practice-guidelines

Mobility hubs	
PRE-CONDITIONS & ENABLING CONDITIONS	***Urban form and layout:*** Mobility hubs can vary in their forms depending on the area in which they operate and their objectives. • Urban mobility hubs: to increase multimodal trips, walking, cycling and public transport • Suburban mobility hubs: to reduce the need for car, increase first and last mile connectivity and improve public realm • Rural mobility hubs: to connect to interurban public transport, improve accessibility and attractiveness, increase/create first and last mile connectivity, bring services to people • National and international hubs: to offer seamless transfer for long-distance door-to-door mobility offer ***Technical aspects / infrastructure:*** • Physical infrastructures: the mobility hub depending on its size and purpose will require dedicated to space next to public transport stations to provide bike sharing services, micro mobility sharing services, shared cars, etc, bike parking etc. Depending on the type and purpose of the hub, the space needs and services provided will different greatly. • -Digital infrastructure to integrate the services under one platform (Maas): information, ticketing • Analysis of transport needs: demographics, residents' needs, mobility habits (mobility data analysis) ***Policy and regulatory / legal framework:*** • Long term planning approach beyond administrative borders (e.g.: metropolitan region) • Integrate mobility hubs in strategic planning and sectoral plans (SUMPs, urban development plans, housing plans for smaller hubs) • Integrated in local, regional and national land use policies to ensure allocation of space • Need for a regulatory framework and clear responsibilities and multilateral commitment for a stable offer

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Mobility hubs	
	• A regulation framework is needed for the functional reallocation of public realm/existing space for transport functions as well as for the use of mobility hubs by private service providers besides (in some cases) public service providers. ***Funding and financing:*** • Needs stable funding • Use public private partnerships ***Project governance and implementation modalities:*** • Need for a multimodal ecosystem • Analyse target audience • Analyse potential stakeholders • Stakeholders engagement and involvements • Community involvement • City involvement • City/ Transport Authority clear leadership (for implementation, financing, branding, design and communication
CONSTRAINTS/ BARRIERS for implementation	• Finding the appropriate location • Transfer between modes need to be easy, attractive and accessible • Space needs and authorization • Stakeholders engagement • Defining clear responsibilities • Data sharing
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	• Lack of visibility and communication • Lack of transport options • Financial viability of the hub
IMPACTS (Indicators & DNSH)	• Increased use of public transport and active mobility by offering various modes of transport solutions in one place. • Enhanced cooperation between transport stakeholder
Additional information from CASE STUDIES	• Mobihub demos installed in Brasschaat and Bergen • SMARTA demonstrator in Groningen Drenthe, the Netherlands

3.3.10 Goods delivery with Drones

- Authors: **VTT**
- Knowledge Repository link: **https://netzerocities.app/resource-518**

Goods delivery with Drones
Following the success of **Unmanned Aircrafts, UAs (drones)** in surveillance and remote sensing, drone delivery systems have begun to emerge as an **alternative to trucks and vans** for handling last-mile delivery. Drone delivery solutions are expected to reduce delivery costs, delivery time, congestion, GHG and local emissions in urban areas and hence free up space at ground level to create healthier, liveable cities.

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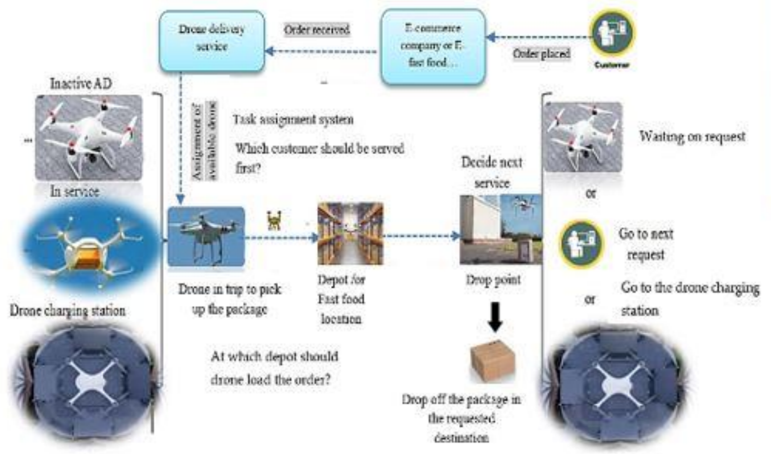
Goods delivery with Drones



Shared autonomous drone package delivery system operations

The drone delivery concept is perhaps the most promising for **sensitive cargo**. The potential use cases are package, food and meal deliveries by drones into private properties, and package delivery into a central delivery hub. Drones have potential also in **time-critical medical applications**, such as the delivery of organs or stored blood.

Most of the developed concepts of drones rely upon **battery electric propulsion systems**, a minority of the developers is working on **hybrid** electric propulsion systems. Among the drone cargo delivery concepts, the **lift + cruise aircraft** is the preferred archetype at present, followed by wingless and vectored thrust. The stated payload of the concepts ranges from 0.7 to 200 kg. Most of the **concepts** are planned to be autonomous during initial operation.

CO-BENEFITS	Drone deliveries may **improve** local **air quality**, **reduce congestion**, **reduce GHG emissions** and **enhance attractiveness of the cities.** Drone deliveries have also the potential to **boost local business**.
KEYWORDS	Drone deliveries are directly connected with solutions such as Electrified urban freight delivery/Last mile delivery, Cooperative Intelligent Transport Systems and Services (C-ITS), Cooperative, connected and automated mobility (CCAM), Route optimisation, Last Mile Delivery, and other smart solutions.
EXTERNAL LINKS	• Benarbia, T.; Kyamakya, K. A Literature Review of Drone-Based Package Delivery Logistics Systems and Their Implementation Feasibility. Sustainability 2022, 14, 360. • EASA: Study on the societal acceptance of Urban Air Mobility in Europe

Goods delivery with Drones	
PRE-CONDITIONS & ENABLING CONDITIONS	***Climate, environment and geography:*** Ensuring that birds and insects are not affected by the service operations; Ensuring that the level, duration and frequency of noise from the operations is kept at acceptable level ***Technical aspects/infrastructure:*** Clarification of the integration of the airspace; taking into account and preparing for cyber security risks; Identifying the need for drone charging stations and/or drone ports ***Policy and regulatory/legal framework:*** Ensuring coordinated actions between all authority levels (EU, National, local) as well as smooth coordination between goods and logistics suppliers; Definition of quiet zones and times

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Goods delivery with Drones	
	Funding and financing: Encouraging through different funding opportunities demonstration and pilot projects to show that the operations work ***Project governance and implementation modalities:*** Supporting the deployment with timely, sufficient and transparent information and dialogue with citizens and stakeholders.
CONSTRAINTS/ BARRIERS for implementation	***Climate, environment and geography:*** The risk of collision with other drones or manned aircraft and crashes due to malfunctioning navigation or bad weather conditions ***Urban form and layout:*** Privacy concerns relating to a drone's ability to record and transmit data in real time (EASA, 2015). Data generated and stored during flight and delivery could be associated with specific individuals and reveal sensitive details of private properties and public buildings ***Technical aspects/infrastructure:*** Availability and location of recharging stations; Battery range limitations; Vehicle landing challenges; Vehicle routing challenges (to avoid empty flights and collisions); Charging process and recharging; Capabilities of urban aerospace to deal with high delivery drone traffic densities; Air safety; International hacking and cyber-attacks; Bad weather conditions; Limited carrying capacity ***Policy and regulatory/legal framework:*** Commercial drone delivery has not been broadly legalized; Insurance obligations ***Economic and social context:*** High operational costs of the delivery systems; Job losses in traditional logistics; Affordability of the services for a large part of society; The risk to the use of delivery drones for illicit purposes, such as smuggling, transport of drugs or weapons, or even terrorist attacks.
INSTRUMENTS/ Processes for implementation	EU level regulation for commercial drone deliveries, Regulation on quiet zones and times. For example: EU REGULATION 2019/947 of 24 May 2019 on the rules and procedures for the operation of unmanned aircraft.
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	Climate, environment and geography: The threat to wildlife, especially birds, is a key concern; The noise generated by the vehicles when they take-off, land and in flight; Visual pollution; CO2 emissions relating to battery production and use and extra warehousing, required by a drone-based logistics system, may reduce or eliminate the benefits Policy and regulatory/legal framework: Ethical issues due to the use of algorithms. Autonomous drones might need to 'make' an ethical decision in situations where harm cannot be prevented because of an incident, such as where to crash, who to injure and what damage to cause Economic and social context: High operational costs of the delivery systems; Job losses in traditional logistics; Affordability of the services for a large part of society; The risk to the use of delivery drones for illicit purposes, such as smuggling, transport of drugs or weapons, or even terrorist attacks.
IMPACTS (Indicators & DNSH)	**Reduction of CO_2 emissions** compared to traditional vehicles (trucks, vans), [g/tonne km]
	DNSH It is still unclear whether drone delivery will simply replace alternative delivery methods or lead to additional delivery trips and increase in GHG emissions. This

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Goods delivery with Drones	
	also highly depends on the type of goods being delivered by drones, the way they would have been delivered in a Business-as-usual scenario, and the existing land-use and transport patterns in which the drones are being used (rural vs. Urban environment). The threat to wildlife, especially birds, is a key concern.
Additional information from CASE STUDIES	Several comparative studies (Figliozzi, 2017; Goldchild and Toy, 2017; Park et al., 2018; Stolaroff et al., 2018) show that delivery drones are more 'CO2-efficient' than conventional means of transport, with the amount of CO2 emissions being greatly reduced, but this depends on a number of specific factors. In short, these studies show that delivery drones can perform better than: • Conventional delivery trucks, as they produce considerably less CO2 emissions when the distance travelled is short, energy requirements are low and number of recipients is small (Goldchild and Toy, 2017); • Diesel vans, with significantly better results when the payloads are small and customers are clustered around one delivery route (Figliozzi, 2017); • Motorcycles, with higher CO2 efficiency achieved in rural than in urban environments (Park et al., 2018). These results should, however, be viewed with caution. They focus on a narrow market, i.e. last-mile delivery to a single or few recipients with low payload. Goldchild, A. and Toy, J., 2017, 'Delivery by drone: an evaluation of unmanned aerial vehicle technology in reducing CO2 emissions in the delivery service industry', Transportation Research Part D: Transport and Environment61, pp. 58-67 Figliozzi, M. A., 2017, 'Lifecycle modeling and assessment of unmanned aerial vehicles (drones) CO2e emissions', Transportation Research Part D: Transport and Environment 57, pp. 251-261. Park, J., et al., 2018, 'A comparative analysis of the environmental benefits of drone-based delivery services in urban and rural areas', Sustainability10, p. 888. EEA Briefing: Delivery drones and the environment
ADDITIONAL LINKS TO EXAMPLES	• New mode for transporting pharmacy products by drone trialled in Helsinki | Mobility Innovation Marketplace (eiturbanmobility.eu)

3.3.11 Electrified urban freight delivery/ Last mile delivery

- Authors: **TNO, EIT-UM**
- Knowledge Repository link: **https://netzerocities.app/resource-528**

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the "orange" fields of this solution, and then it has been afterwards reviewed by JRC and completed the "pink" fields, and the Knowledge Repository content has been updated with JRC's input. So, here only the "orange" fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

Electrified urban freight delivery/ Last mile delivery
Electrified urban freight delivery and other sustainable options for **last mile delivery** can be promising climate and energy solutions to reduce emissions coming from logistics, in the effort to contribute to low-emission zones as these are now envisaged in a number of cities. Solutions such as **shifting to electric vans**, **micro-depots with zero-emission last-mile deliveries**, **cargo bikes**, or even implementing a **hub** for a certain freight flow can be developed for various sub-sectors within urban freight (e.g. retail, parcels, etc.). Such actions or policies can bring significant effects in terms of energy consumption and reducing CO2 in logistics which are useful to be measured by cities, also for them to be able to discuss with local urban logistics actors.

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This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

Electrified urban freight delivery/ Last mile delivery

Outlook of city transport: logistics, hinterland and continental freight transport. Source: Topsector Logistics/TNO (2021).

There are **tools** that have been developed to **measure such effects** and assess the solutions. Specific **modules for zero emission zones for city logistics**, modelling all vehicle movements by light commercial vehicles and trucks that relate to trips in and around urban areas can be included. Within such modules, methods to **map the size of urban logistics vehicle fleet** and (de)compose this vehicle fleet regarding specific logistical segments (e.g. construction, retail, parcel, waste) and measure the impact in terms of kilometres and CO2-emissions (inside and outside the urban areas) can be used. The impact of **tailored measures** for the different segments with respect to a change in emissions, kilometres and vehicle types can be measured. Mapping the size and measuring the impact of potential measures could be done on a national, regional, urban or neighbourhood/building level.

CO-BENEFITS	Solutions for zero emission urban freight delivery primarily aim to **reduce GHG emissions** and **reduce energy needs**. When applied on a local (urban) level with the zero-emission zone module, they also contribute at **improving air quality** and **reducing noise pollution**. Overall, such solutions can offer further liveability effects such as **enhancing attractiveness of cities**, better access to living areas for all, **healthier and more attractive lifestyles** and improving land use management.
KEYWORDS	It is directly linked with solutions such as transport electrification, urban freight delivery, last mile delivery, sustainable city logistics. It can be also connected to other service solutions, environment, climate mitigation, and vehicle solutions. Measures and behavioural responses to decarbonize city logistics as well as other logistical models to reduce the number of vehicle kilometres (e.g. hubs or collaboration) require more validation in order more specifically calculate the effects of the tools. The possibilities differ per business, but in general it relates to the underlying business model, stakeholder engagement and collaboration and replication of pilots/experiments.
EXTERNAL LINKS	• TDA whitepaper - Zero Emission Urban Freight • https://www.polisnetwork.eu/wp-content/uploads/2020/12/ZEZ-F_How-to-Guide_low.pdf • https://frevue.eu/publications/

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Electrified urban freight delivery/ Last mile delivery	
	• https://www.tno.nl/nl/aandachtsgebieden/mobiliteit-logistiek/roadmaps/sustainable-traffic-and-transport/sustainable-mobility-and-logistics/duurzame-logistiek/co2-uitstoot-logistiek/ • https://repository.tno.nl/islandora/object/uuid%3Ad14b3031-cab3-4a13-a0db-a970ef188143
EXAMPLES	• Prague successfully implements cargo bicycle hubs to reduce freight congestion in the inner city | Mobility Innovation Marketplace (eiturbanmobility.eu) • Toulouse – RAPTOR Project

3.3.12 Fleet decarbonisation

- Authors: **REGEA**
- Knowledge Repository link: **https://netzerocities.app/resource-538**

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Fleet decarbonisation	
Commercial fleet is a group of vehicles utilized by a company to pursue its business objectives, regardless of whether persons or freight are being transported. Any type of vehicle can be included in the commercial fleet; however, aviation, shipping and road freight transport are deemed the most difficult sectors to decarbonise. Specific **challenges** also exist in reducing the GHG emissions of the mining and construction fleets. Different measures can be taken for the purpose of **reducing the carbon footprint of commercial fleets** (e.g. route, freight or speed optimisation, improving vessels' propulsion efficiency, fuel efficiency etc.), however, **retrofitting and/or replacing vehicles fuelled by conventional fuels** (mostly diesel) with "**greener" options** has the greatest impact. In the **shipping sector**, **slow steaming and biofuels** can reduce emissions by up to 79%. **Wind-assisted propulsion** could deliver more than 50% of energy required by a ship's main engine when slow steaming. **Electric propulsion** is being trialled on a small scale. For all types of fleets, the emission reductions from using **hydrogen** depend on the carbon-footprint of the electricity production process. In **road freight transport**, for light and medium trucks, an extensive use of **batteries** is possible, whereas heavy trucks rely most on the development of **hydrogen fuel cells**.	
CO-BENEFITS	Retrofitting and/or replacing fossil-fuelled fleets with vessels and vehicles based on biofuels, electricity, hydrogen and similar sustainable solutions can **reduce GHG emissions.** With measures to increase propulsion and fuel efficiency, it is possible to significantly **reduce energy needs** of the commercial fleets. Shortening of the supply chains (including route optimization) can be used to **boost local businesses**. A switch to non-fossil fuels will **improve air quality** and can **reduce noise pollution**, thus having a potential to **enhance attractiveness of the cities**. It will also **reduce ecological footprint**, which can be especially relevant when it comes to ecological risks for the water bodies (accidents with fuel leaks).
KEYWORDS	Fleet decarbonisation has direct connection with other mobility related solutions, such as integrated EV charging solutions, Vehicle solutions, Infrastructure solutions, or Service solutions. It has indirect link with other solutions such as green hydrogen technologies, fuel cells, green hydrogen thermochemical processes,

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Fleet decarbonisation	
	green hydrogen biological processes, sustainable biofuel from biomass fermentation process, or sustainable biofuels from biomass thermochemical process.
EXTERNAL LINKS	• M. Sharmina, O. Y. Edelenbosch, C. Wilson, R. Freeman, D. E. H. J. Gernaat, P. Gilbert, A. Larkin, E. W. Littleton, M. Traut, D. P. van Vuuren, N. E. Vaughan, F. R. Wood & C.Le Quéré (2021) Decarbonising the critical sectors of aviation, shipping, road freight and industry to limit warming to 1.5–2°C, Climate Policy, 21:4, 455-474. DOI • https://www.etp-logistics.eu/alice-launches-the-roadmap-towards-zero-emissions-logistics-2050/ • Fúnez Guerra, C., Reyes-Bozo, L., Vyhmeister, E., Jaén Caparrós, M., Salazar, J. L., Godoy-Faúndez, A., … Verastegui-Rayo, D. (2019). Viability analysis of underground mining machinery using green hydrogen as a fuel. International Journal of Hydrogen Energy. DOI • Teoh, T.; Kunze, O.; Teo, C.-C.; Wong, Y.D. Decarbonisation of Urban Freight Transport Using Electric Vehicles and Opportunity Charging. Sustainability 2018, 10, 3258. DOI

3.3.13 Car sharing

- Authors: **EIT-UM**
- Knowledge Repository link: **https://netzerocities.app/resource-558**

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Car sharing
Owning and operating a personal vehicle in cities is becoming increasingly inefficient and costly. **Car sharing systems** provides access to a car for users who might not own a car, because they do not need it for daily journeys or cannot afford a private vehicle. They can also be used by companies and authorities for their fleet management.  *Flickr Automobile Italia*

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<table>
<tr><th colspan="2">Car sharing</th></tr>
<tr><td colspan="2">Car sharing models present a reliable, flexible, and cost-efficient alternative to car ownership that supplements the sustainable modes of walking, cycling and public transport. Though they are generally not run by the city in which they operate, the municipality can set up a supportive infrastructure, and establish appropriate policy and legislation to integrate car sharing into the city fabric and with public transport (1).

There are different forms of car sharing. With a station-based model, customers pick up and return the vehicle from a fixed rental station (2). This type of service does not give great flexibility to the user but is convenient for reliable vehicle fleet tracking. The second type of car sharing service is the model based on free-floating operations. This model does not require pre-booking and registration of a return time, giving more flexibility to the user compared to the station-based model. However, availability of vehicles is not guaranteed and reserved parking spots for return may be limited within the city.

Transitioning from private vehicle ownership to car sharing systems can bring social benefits such as growing financial well-being of the population achieved through saving on car purchases, reducing the space taken up by parked cars, lower consumption of resources used for the manufacturing of cars, and less waste associated with the operation of vehicles (3). Car-sharing, especially when using electric vehicles and renewable energy sources, can contribute to climate mitigation and air pollution prevention.</td></tr>
<tr><td>CO-BENEFITS</td><td>Car sharing models, especially when using electric vehicles and renewable energy sources can assist with the reduction of GHG emissions and noise pollution, and the improvement of air quality. As resources are shared, they form part of the sharing economy and can contribute to the reduction of energy needs and maintenance costs. Furthermore, they can be used to raise awareness and as an incentive to behavioural change. As less cars and parking spaces are required, they also enhance the attractiveness of the cities.</td></tr>
<tr><td>KEYWORDS</td><td>Car Sharing solutions have direct link with other solutions such as Mobility Management, Mobility as a Service (MaaS) for multimodal integration, or collective passenger transport.</td></tr>
<tr><td>EXTERNAL LINKS</td><td>References from the text:
• Implementing a large car sharing system
• Free Floating vs. Stationary vs. P2P: Car-sharing Technology Providers Open the Door to New Options
• A Handbook on Sustainable Urban Mobility and Spatial Planning</td></tr>
<tr><td>EXAMPLES</td><td>• Car-Sharing Action Plan for Bremen
• CarSharing in Denmark</td></tr>
</table>

3.3.14 Shared micromobility

- Authors: **EIT-UM**
- Knowledge Repository link: **https://netzerocities.app/resource-578**

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Shared micromobility
Shared micromobility is "the **shared use of a bicycle, scooter, or other low-speed mode** enabling users to have **short-term access** to an active or low-speed motorized transportation mode **on an as-needed basis**" (IGI Global).

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Shared micromobility

In recent years, **electrification** of vehicles has led to new shared micromobility services (e.g. shared e-bikes, e-scooters, e-skateboards, e-mopeds). Due to their **affordability**, 24/7 **availability** and **flexibility** of routes, they have experienced a rapid growth in uptake, especially among low-income users.

Source: https://www.bbc.com/news/uk-48106617

Shared micromobility can become a **cost-efficient solution** to challenges such as the reduction of traffic congestion. It can contribute to the transition to more sustainable mobility modes and, if using renewable energy sources, provide a green alternative for urban freight transportation, especially last mile delivery logistics (e.g. e-cargo bike sharing). Other potential benefits include the reduction of private vehicle ownership and therefore lower consumption of resources.

Shared micromobility **infrastructure** is generally **cheaper and easier to build and maintain** than road infrastructure, though user safety and the integration with other sustainable mobility services must be ensured. Shared micromobility devices are classical feeders to public transport systems. Integration of shared mobility services into public transport networks can be done through the use of smart cards/ transport apps, integrated ticketing systems and multi-modal marketing campaigns.

Source: https://www.mobil.nrw/flexible-mobilitaet/blog/velocity-aachen-bezahlbare-elektromobilitaet-fuer-alle.html

However, shared micromobility poses **some challenges to cities**, e.g. the invasion of public space and unregulated parking, vandalism and short lifecycle of devices, emissions from shared vehicle transport for repositioning or recharging, user safety or the use of data generated by shared micromobility. To tackle these challenges, cities might consider to regulate speed limits, parking, technical features, individual protection equipment, minimum age or data exchange. New technology, such as swappable batteries, may help to optimize the logistics of collecting electric vehicles for charging.

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Shared micromobility	
CO-BENEFITS	Shared micromobility services enable cities to **reduce GHG emissions** and **improve air quality**. Less vehicles on the streets will furthermore **enhance the attractiveness of the cities** and **improve land use management**. Through the **promotion of active mobility**, they also lead to **healthier and more attractive lifestyles**, better physical activity of individuals and better access to **living areas**. As resources are shared, they form part of the **sharing economy** and can contribute to the reduction of energy needs and maintenance costs. Furthermore, they can be used to **raise awareness** and as an incentive to **behavioural change**.
KEYWORDS	Shared micromobility is directly linked with solutions such as integrated land use and transport planning; Sustainable Urban Mobility Plans (SUMPs); Integrated EV/e-bikes Charging Infrastructure; Public charging infrastructure for EVs; Walking, cycling and micromobility infrastructure; Mobility Management, Mobility as a Service for multimodal integration; or collective passenger transport.
EXTERNAL LINKS	• Benefits of micro mobility in cities • Micromobility: the new urban mobility • The rise of micromobility (The Urban Mobility Observatory) • Safe use of micromobility devices in urban areas (SUMP Topic Guide, European Platform on Sustainable Urban Mobility Plans)
EXAMPLES	• Cargo bike sharing to launch in Stoke Newington, London Fields and Shoreditch

3.3.15 Collective passenger transport

- Authors: **UITP**
- Knowledge Repository link: **https://netzerocities.app/resource-608**

Collective passenger transport

Collective passenger transport can be defined in two **categories**:
• **Conventional and high capacity public transport**, which consists in transporting collectively citizens from one place to the other. Public transport systems usually operate along established routes and are managed on a schedule or timetable. The typical examples of mass public transport systems are buses, trains, trams, trolleybuses, or waterborne transport systems. High capacity public transport systems are the backbone of urban mobility and are considered as goods of common public interest. They play a vital role in creating healthy, inclusive and sustainable cities and regions.
• **Shared mobility** which consists in passenger transport service which is available for use by the general public on the basis of demand and adjustable to individual needs (demand responsive/self-service). It consists in providing mobility solutions that can be shared collectively. Shared mobility can be divided in 3 categories:
    ◦ Shared mobility for first and last mile transport such as car/bike/scooter sharing
    ◦ On-demand collective transport such as: ride-hailing, demand responsive transport
    ◦ Informal transport systems: such as privately-owned minibuses, taxis etc. which usually operate in unregulated environments
 	
Other forms of collective transport such as **employee transport or leisure transport** (coaches), are usually not considered as public transport services.

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Collective passenger transport

Public transport systems can either be publicly or privately owned or operate under a public/private partnership (PPP). The public transport systems require **stable funding and financing for capital investments and operations** in line with the expected quality standards, transport coverage and frequency levels. In order to ensure both the **legal framework and capacity** to deploy locally earmarked revenue from either existing or new sources, this requires the definition and establishment of diverse mechanisms to cover the costs of operating and maintaining the transport systems.

Examples of public and private financing to raise funds for public transport are:

- Property developers' contributions
- Levies of parking places
- Taxes on salaries
- Taxes on cars spent on improving public transport
- Tax on fuel which are invested into to local transport

The advantages of **good public transport networks** are not only confined to the passengers. A **study of Barcelona** in 2021 showed that for every €1 spent in public transport, the return on investment within the region was €6.5. Urban and local public transport services in Europe contribute between €130-150 billion per year to the economy, this equals 1.0-1.2% of GDP. Many sectors such as the construction industry, the supply industry, manufacturing, and IT services are recipients of these investments.

Because the mobility sector has a **wide variety of actors**, authorities are encouraged to regulate these innovations to foster sustainable business models and ensure they cater for the public good.

CO-BENEFITS	Collective passenger transport can have a wide variety of co-benefits, such as **reduce GHG emissions**, **reduce energy needs**, boost local businesses, **proximity economy**, **social cohesion**, increase employment rate and jobs, raised awareness/behavioural change, **improved access to job opportunities**, improve air quality, reduce noise pollution, reduce road danger, **enhance attractiveness of the city**, healthier and more attractive lifestyles, better physical activity of individuals, **better access to living areas** for all, or reduce ecological footprint.
EXTERNAL LINKS	• Better Urban Mobility Playbook (UITP) • Video: https://www.uitp.org/campaigns/mobility-for-life

Collective passenger transport	
PRE-CONDITIONS & ENABLING CONDITIONS	There are not one size fits all aspects regarding the governance of public transport systems. The governance of urban transport systems is a product of wider arrangements for the governance of metropolitan areas. These in turn are embedded in wider commonly held national conceptions and legacies which can very between nations. These include: • The relationship between the role of the state and the private sector

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<table>
<tr><th colspan="2">Collective passenger transport</th></tr>
<tr><td></td><td>

The relationship between the roles of national and sub-national Government
The strength of, and degree of trust in, public institutions

To operate efficiently, public transport systems need the support of strong transport political commitment with long term vision, goals and implementation strategies. These can be reached through the creation of governing agencies such as public transport authorities in charge of managing and coordinating transport and mobility around the city and that work also hand in hand with urban planning.

Technical aspects / infrastructure:
Public transport systems require massive investments on infrastructure needs. Infrastructure needs will be different from one type of transport to another. Bus transport requires in general less investments in infrastructures than rail transport (trams, metros and trains).

Policy and regulatory / legal framework:
Legal framework based on national, regional and EU laws
Need for a regulatory framework and clear responsibilities under a transport authority with a vision and strategy. The regulatory framework determines the way in which transport services are designed, planned and produced. Therefore, transparent rules have to be established between the different agents of the systems. Operators from different modes and authorities from different jurisdictional levels have to co-exist both in time and in space.

Integrated mobility and urban planning approach
Mobility planning needs to be coordinated with urban planning. For this a long-term planning approach beyond administrative borders (e.g.: metropolitan region) is needed. This can be achieved by creating a unified plan and vision for the city/metropolitan area focusing on the principles of quality of life and sustainability, densification, mass public transport and active mobility; e.g.: strategic planning and sectoral plans (SUMPs, urban development plans, housing plans for smaller hubs).
Reinforced cooperation between the public and private sectors

Funding and financing:
The public transport sector requires stable funding and financing for capital investments and operations in line with the expected quality standards, transport coverage and frequency levels.
In order to ensure both the legal framework and capacity to deploy locally earmarked revenue from either existing or new sources, this requires the definition and establishment of diverse mechanisms to cover the costs of operating and maintaining the transport systems.
Funds can come from various sources:
National / regional funds

EU funds
Public and private financing such as:
Property developers’ contributions
Levies of parking places
Taxes on salaries
Taxes on cars spent on improving public transport
Tax on fuel which are invested into to local transport

</td></tr>
<tr><td>CONSTRAINTS/ BARRIERS for implementation</td><td>
The challenges of urban transport are many but they include getting the balance right between:

Funding and financing
Spending available resources on maintaining existing infrastructure
Expanding the infrastructure facilitating different types of journeys made by different types of people

</td></tr>
</table>

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Collective passenger transport	
	• Funding raised from the users of public transport networks and funding raised from taxation and other sources • Competition and regulation in the public interest
INSTRUMENTS/ Processes for implementation	Need for a Transport Authorities or governing bodies in charge of organising and managing the transport systems Contractual relationships between the authority and the operator Public Private partnerships
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	Digitalisation can lead to loss of front-end jobs and less customer services
IMPACTS (Indicators & DNSH)	Urban economies cannot function with transport. Public transport and active mobility help address as well the following challenges: • Reducing carbon emissions and air pollution • Reducing social exclusion by providing affordable, acceptable, accessible and available access to opportunity • Contributing to wider urban climate resilience • Supporting urban economies by reducing congestion and making better places that people want to spend time in

CARBON EMISSIONS ABATEMENT FROM CONNECTED CITIES[21] (tCO_2e/year)

	UK	Germany	Spain	France	USA	Europe
Connected Cities	435,000	498,000	226,000	383,000	1,990,000	3,018,000
Parking space monitoring	9,000	12,000	6,000	12,000	260,000	74,000
Smart bins	20	20	10	10	70	100
Street lighting	108,000	42,000	8,000	5,000	31,000	202,000
Traffic congestion management	38,000	61,000	40,000	45,000	212,000	403,000
Traffic congestion monitoring (road signs)	149,000	204,000	92,000	170,000	372,000	1,281,000
Traffic congestion monitoring (traffic lights)	131,000	179,000	81,000	150,000	1,116,000	1,057,000

Source: GeSI, Mobile Carbon Impact, 2016

Additional information from CASE STUDIES	• Better Urban Mobility Playbook (UITP, 2021) • How to build successful cities (UITP, 2021) • Transport authorities for metropolitan areas (UITP,2022)

3.3.16 Mobility as a Service (MaaS)

- Authors: **UITP, CARTIF**
- Knowledge Repository link: **https://netzerocities.app/resource-628**

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Mobility as a Service (MaaS)

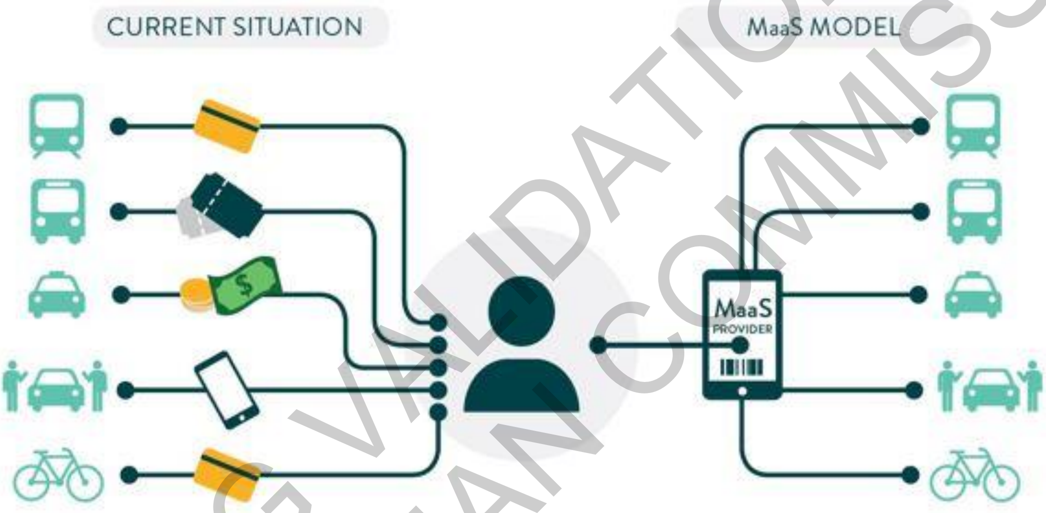
The number of mobility services is growing rapidly, yet for the user it can be challenging to confront all these options when choosing the best way to travel. This is where the **Mobility as a Service (MaaS)** concept steps in: MaaS is about taking away the hassle of finding the most suitable mobility option. It plays a role to change **mobility habits** by providing travellers with multiple transport options under one system. From a transport perspective, Maas is offering better services with a wide range of options, therefore attracting more customers.

MaaS can be defined as the **integration of, and access to, different transport services** (such as public transport, ride-sharing, car-sharing, bike-sharing, scooter-sharing, taxi, ride-hailing, etc.) in one single digital mobility offer, with an efficient public transport system and active mobility as its basis. This tailor-made service suggests the most suitable solutions based on the user's travel needs.

MaaS systems can offer:

- integrated planning,
- integrated booking and payment,
- on route information to provide easy mobility.

There is a diversity of MaaS Platforms. Maas initiatives are built at local, as well as national and global level.



Mobility as a Service. Source: UITP ref doc: UITP Report Mobility as a Service, April 2019

To set up a MaaS solution, a **good public transport system** as well as **adequate walking and cycling conditions** and combined mobility services need to be available. This introduces the question of which key services, whether public or private, a MaaS solution should offer in order to propose a convincing alternative to car ownership. Public transport is the backbone product of any MaaS offer, but car-based services are also considered core products to attract car owners and offer a complete mobility solution. The physical integration and information of actives modes, scooters, parking or park-and-ride facilities add as well to the convenience and success of the service.

CO-BENEFITS	MaaS increases **technological readiness** of systems that use it. They also enable **improved access to information** to passengers and users of mobility services. They can participate in a **healthier and more attractive lifestyles** as they enable an improved access to information on the available mobility services and participate in **raising awareness and behavioural changes** in terms of mobility.
EXTERNAL LINKS	• UITP ref doc: UITP Report Mobility as a Service, April 2019 • https://maas-alliance.eu/homepage/what-is-maas
EXAMPLES	***Valencia: SUMA card https://atmv.gva.es/es/suma*** The SUMA card can be used through the Metropolitan Area of Valencia using different types of transport agencies: Metrovalencia, EMT, RENFE Cercanías and MetroBus, as well as urban transport in some municipalities (Paterna and Sagunt).

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Mobility as a Service (MaaS)	
	This new ticket also allows you to make a free transfer between different means of transport or between two different EMT or MetroBus lines or the urban operator Paterna or Sagunt. The rates of the ATMV titles fall between 11% and 55% compared to the operators' own titles. This discount is even greater if one takes into account that the number of zones has been reduced, a new operator has been added to the integrated tickets (RENFE Cercanías) and that there is the possibility of making a free transfer. In addition, currently until July 31, 2023, a 50% discount is applied to the retail prices of SUMA monthly, SUMA monthly Jove and SUMA 10.
CONSTRAINTS/ BARRIERS for implementation	***Political*** Set up the market rules (regulator/policy makers); should present all options available; data sharing. ***Economic*** Investments in the system. ***Social*** Social trust (reliable, simple, user friendly); digital accessibility and literacy. ***Technical*** The role of the integrator can be taken by different actors (PTO, PTA, MaaS company or companies from banking, telecommunications sector, etc.); MaaS requires a business ecosystems where multiple organisations act in collaboration; Data. ***Legal*** Data exchange and access

3.3.17 Cooperative Intelligent Transport Systems and Services (C-ITS)

- Authors: **Rupprecht**
- Knowledge Repository link: https://netzerocities.app/resource-498

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the "orange" fields of this solution, and then it has been afterwards reviewed by JRC and completed the "pink" fields, and the Knowledge Repository content has been updated with JRC's input. So, here only the "orange" fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

Cooperative Intelligent Transport Systems and Services (C-ITS)
Cooperative Intelligent Transport Systems (C-ITS) characterises the more modern version of ITS where communication among vehicles using wireless technology is possible, which enables them to interact not only with each other but also with the road infrastructure and even with pedestrians or cyclists. Such functionalities enable a **coordination and cooperation between road users**, which allow for the advanced **management** of traffic and mobility, and can serve as technological basis for new mobility solutions (e.g. CCAM, MaaS).

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Cooperative Intelligent Transport Systems and Services (C-ITS)

Source: Cooperative Intelligent Transport Systems, Die Autobahn GmbH des Bundes

Through enhanced cooperation and traffic management, C-ITS can **reduce congestion and increase the quality of transport services**, delivering better **accessibility** and improved mobility for all. In this way, C-ITS constitutes an effective instrument for existing over-burdened traffic systems to implement innovative, sustainable visions tackling traffic movements and at the same time visualizing, monitoring and constantly evaluating traffic situations. As **exchange of data and information** are made possible through C-ITS, facilitating a more harmonized intermodal traffic infrastructure, services like dynamic lane changing, alternative route choice, improved traffic signalization, could be established. C-ITS capabilities can significantly improve road safety, through the cooperation of the different road users and the implementation of support functionalities to minimise human-errors resulting in traffic accidents.

Source: https://www.c-its.kr/english/introduction.do

C-ITS also enables a more efficient use of road space, by means of an **optimised traffic flow** and performance. Finally, it facilities eco-driving and provides opportunities to prioritise sustainable modes, resulting in reduced pollution and GHG emissions (climate protection). A more efficient and sustainable multimodal mobility network can thus be developed, with innovative services which can better address user needs and shift their travel behaviour towards more environmental friendly modes.

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Cooperative Intelligent Transport Systems and Services (C-ITS)

Source: Be-mobile.com

CO-BENEFITS	Introduction of C-ITS in traffic infrastructure would **increase technological readiness** for the society, through enhancement of digital infrastructure and connectivity, and its utilisation by transport users. The advanced management of network and traffic services and flow through C-ITS solutions, has the potential to **improve air quality** and **reduce noise pollution**, by promoting safer, more efficient and sustainable driving behaviour and modal choice, simultaneously **reducing hot spots** and **road danger**. In this way, C-ITS can also **enhance the attractiveness of cities**, provide **better accessibility** for all, and create a suitable environment to steer innovation and new profitable mobility industries, and to **increase employment rate and jobs**.
KEYWORDS	C-ITS is directly linked with CCAM.
EXTERNAL LINKS	• https://www.eltis.org/sites/default/files/the_role_of_intelligent_transport_systems_its_in_sumps.pdf • C-ITS.pdf (autobahn.de) • White Paper on (future) C-ITS Service Implementation • Briefing: Cooperative Intelligent Transport Systems (C-ITS) | ETSC • https://www.car-2-car.org/about-c-its

3.3.18 Parking policies, management and fees, smart parking

- Authors: **TNO**
- Knowledge Repository link: **https://netzerocities.app/resource-638**

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the “orange” fields of this solution, and then it has been afterwards reviewed by JRC and completed the “pink” fields, and the Knowledge Repository content has been updated with JRC’s input. So, here only the “orange” fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

Parking policies, management and fees, smart parking
Stakeholders, such as city authorities, companies, experts and planners have to make various complex decisions in the **urban planning process**, with designing sustainable and future-proof road infrastructures being one of the many complicated tasks. An example includes design decisions for scope and **suitable locations for parking** and choosing appropriate **tariffs**.

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Parking policies, management and fees, smart parking

A complicating factor is that **design decisions** should take into account the future responses of the population. For example, when **additional free parking locations** are created for people visiting the beach, it may very well be the case that other people start using the cheap parking for shopping purposes. Therefore, to improve evaluations of urban designs while considering and better predicting the (potential) user responses of a population in the process, **digital support** could be incorporated. This can be done via **modelling and simulations**, where optimization, e.g. of potential parking locations, can be applied to urban design decisions. Digital twinning platforms can accelerate and improve spatial planning in the urban environment by extracting information from improved, interactive computer models, while also taking into account various responses of various user groups. In that respect, **parking policies, management and fees, smart parking solutions** can also be tested in order to identify their **impacts on the transport system**.

With respect to **smart parking**, already various tools for its applicability: apps (PaaS), IoT/sensor technology, the use of real-time data for parking availability etc.

All the above can contribute to behavioural change through **emission-based parking fees**, as an incentive to use lower or zero-emission vehicles, more efficient mobility planning leading to shorter journeys and thus easing congestion of traffic, as less people are circulating to look for parking.

CO-BENEFITS	Digital twinning platforms used for this solution allow to investigate what-if scenarios. This includes measures that **enhance the attractiveness of the cities** and aim for **better access to living areas** for all. Such solutions can also **boost local business**. Overall, they aim to **reduce GHG emissions** and energy needs (congestion reduction as less vehicles circulating in search of parking), therefore also achieving **improvement of air quality**, **reduction of noise pollution**, as well as **reduction of road danger.**
KEYWORDS	It has a direct connection with other solutions such as parking policies, smart parking, management and fees, or spatial planning. As well as more general with planning and regulation, mobility management, or modelling approaches.
EXTERNAL LINKS	• Smart and safe traffic transport (TNO focus area Traffic and Transport) • What is a smart parking system? Functionalities and benefits (tomorrow.city) • Positively Promoting Parking Solutions for Sustainable Mobility (European Parking Association - EPA)

3.3.19 Smart cards

- Authors: **UITP**
- Knowledge Repository link: **https://netzerocities.app/resource-658**

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the "orange" fields of this solution, and then it has

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Smart cards

Smart cards can be defined as a device, generally bank card size, made of an embedded integrated circuit, encapsulated in a plastic body. The **contactless smart card communicates** with and is powered by the reader through **radio-frequency (RF)** induction technology, within a few centimetres distance.

The contactless smart card is secure, affordable and can be **used for many services**: the same smart card could be used for public transport, payment services, loyalty, and so on with a dedicated application for each service. The smart card is used to **hold ticketing data** (loaded value, tickets or passes) in a secure way and every transaction (product loading or validation) is done through an encrypted secure session.

Well-known **smart cards** in the **public transport sector** are the Oyster card (London), Octopus (Hong Kong) and Navigo (Paris). In these cards, the travel information and the rights to travel are stored physically within a chip embedded in the card itself.

Card-centric solutions have become standard for public transport systems because they are flexible, secure, easy to use and have reduced operating costs.

CO-BENEFITS	Smart cards **increase technological readiness** of public transport systems. Thanks to their easy use and payment they can **enhance the attractiveness of the city** and encourage people to participate in **healthier and more attractive lifestyles**.
EXTERNAL LINKS	• Demystifying ticketing and payment in public transport (UITP)

3.3.20 Multimodal ticketing

- Authors: **UITP**
- Knowledge Repository link: **https://netzerocities.app/resource-688**

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the “orange” fields of this solution, and then it has been afterwards reviewed by JRC and completed the “pink” fields, and the Knowledge Repository content has been updated with JRC’s input. So, here only the “orange” fields developed by WP10

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partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

Multimodal ticketing

Public transport companies have **different types of tickets**, providing a variety of services, from single tickets (one-journey ticket, zonal or origin-destination tickets) to single-modes and multi-modes tickets (combining multiple operators), etc. To facilitate boarding and transaction but also the integration of different modes under **one card or system**, transport authorities are pushing moving towards **electronic ticketing, multimodal ticketing and smart cards**.

Multimodal ticketing is a means to provide **multiple travel options** to the passenger under one transport card or device. It increases the accessibility of different systems and facilitates the transfer between the modes. Today with ICT, **electronic ticketing** is a tool that benefits both the passenger and the public transport or mobility services as it enables **combining trips and modes in one single tool** that can either be a contactless ticket card, a bank card, a multi-application card or an NFC (Near Field Communication)-enabled mobile device or online remote loading.

Multimodal ticketing requires a **strong cooperation between the different operators**. Multimodal ticketing is usually account based, meaning that the fare-collection system in which the proof of entitlement to travel and records of travel are held in the back office, on servers and not necessarily on any physical media held by the passenger.

Account Based Ticketing differs from traditional card-based schemes because the business rules and fare calculation are managed in the back-office and the fare is calculated and billed after the trip is complete. This means that the fare-media used to tap in and out of the system is nothing more than a unique identifier for the customer linked to their account. Multimodal ticketing paves the way towards MaaS (Mobility as a Service).

CO-BENEFITS	Multimodal ticketing is a tool that can **increase technological readiness** of public transport systems. Thanks to its easy use, it can **enhance the attractiveness of the city** and encourage people to participate in **healthier and more attractive lifestyles**, considering the possibilities offered by multimodal mobility. **Improved access to information** can be further achieved via such a tool.
EXTERNAL LINKS	• Towards EU-wide Multimodal Ticketing and Payment Systems (FSR publication) • Demystifying ticketing and payment in public transport (UITP report publication)

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This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

3.3.21 Multimodality

- Authors: **Rupprecht**
- Knowledge Repository link: **https://netzerocities.app/resource-698**

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the "orange" fields of this solution, and then it has been afterwards reviewed by JRC and completed the "pink" fields, and the Knowledge Repository content has been updated with JRC's input. So, here only the "orange" fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

Multimodality

To encourage and facilitate a shift from private vehicles to more environmentally-friendly means of transport, all means of transport need to be considered when planning for citizens' mobility needs. Within the last years, many innovative mobility solutions, like on-demand services, shared mobility & micro-mobility or even automated services have emerged in European cities and have disrupted the conventional mobility system that is shaped by mono-modal transport. With these new offers, **multimodal transport**, defined as the use of several different forms of transport for different travel needs and journeys, and **inter-modal trip chains** have become a competitive and viable alternative to private car usage.

Source: https://www.eltis.org/in-brief/news/new-mobility-hub-guidance-published

While the new services are growing in popularity they ought not to replace but rather **complement public transport systems** and active modes. In that way, multi-modal, integrated, and robust public transport systems that function as the backbone of mobility is central to sustainable mobility systems.

There are **two important drivers** that can increase the viability of multimodal transport:

4. **Multimodal digital platforms** allow for a variety of mobility services made available to users via an app. These apps usually include functions such as route planning and navigation as well as ticketing. The means of transport that can be accessed through these platforms should be as wide as possible and include also private mobility providers. An advanced version of this is Mobility as a Service (MaaS).
5. **Mobility hubs** are a means to seamlessly link various modes of transport in order to enable inter-modal trip chains as an alternative to the private car. Mobility hubs link the use of traditional means of transport such as bicycles or cars with public transport (e.g. Bike & Ride or Park & Ride at train stations). Nowadays, mobility hubs also allow easy access to new forms of mobility or shared transport due to the widespread use of digital or smartphone-based information and mobility services.

CO-BENEFITS	By regularly changing from the car to other means of transport like bikes and public transport, the **traffic density will decrease**. This will lead to a **reduction of GHG emissions** and **noise pollution** as well as **improved air quality**.

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Multimodality	
	Less traffic also means **less space needed for parking** thus an improvement in **land use** can be considered as one of the co-benefits that also **enhances the attractiveness of the cities**. By promoting multimodal mobility and at the same time pointing out the advantages of substituting the private car a **change in behaviour of citizens** can be achieved. Especially replacing the means of transport for short trips with a bicycle or with walking, leads to a **healthier and more attractive lifestyle** and better physical activity of individuals.
KEYWORDS	It is directly connected to solutions such as: Fostering cycling, Mobility hubs, Shared micromobility, Land use planning and urban space management, SUMPs, Fostering walking, Multimodal ticketing, Parking policies, or MaaS.
EXTERNAL LINKS	• A planner's guide to the Shared Mobility Galaxy • ShareNorth Mobility Hub Guidance • https://como.org.uk/wp-content/uploads/2019/10/Mobility-Hub-Guide-241019-final.pdf • UITP knowledge brief on Combined Mobility

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3.4 Green Industry

- **Knowledge Repository: Green Industry:** https://netzerocities.app/resource-2643

Table 6: Green Industry solutions

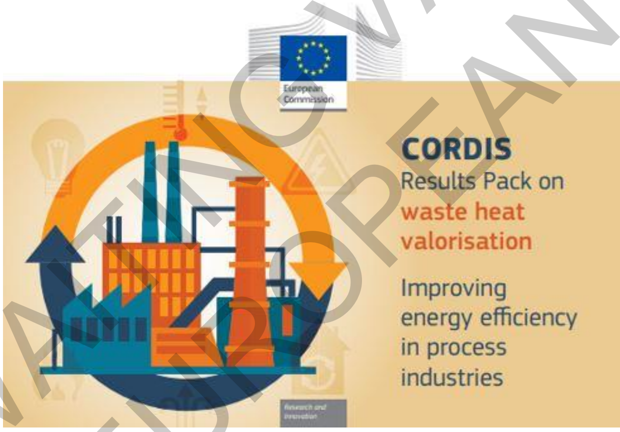
Green Industry		Section
Energy Efficiency in Industrial Processes	Heat Recovery & Valorisation	3.4.1
	Energy Management Systems	3.4.2
	Monitoring Systems	3.4.3
	Replacement of equipment	3.4.4
Renewable Generation for Industrial Processes	Solar Thermal in industries	3.4.5
	High Temperature Heat Pumps	3.4.6
	Green Hydrogen Technologies in green industry	3.4.7

3.4.1 Heat Recovery & Valorisation

- Authors: **Tecnalia, CARTIF**
- Knowledge Repository link: **https://netzerocities.app/resource-1398**

Heat Recovery & Valorisation

Excess heat from certain processes can be a valuable resource for other processes within the **industry** and even for other industries or users, directly or after some transformation steps. In general industries have implemented solutions as long as these were **cost-effective**. However, **heat recovery potential** is still untapped due to a number of technical and non-technical barriers. Among them, the need to make the recovery cost-effective and the real possibility of reusing it by upgrading temperatures or transforming the heat. Capturing low-grade heat for reuse elsewhere is usually not practical or economically viable.



CORDIS. Results Pack on waste heat valorisation: https://op.europa.eu/en/publication-detail/-/publication/688097a1-8aee-11ec-8c40-01aa75ed71a1

Current **innovative solutions** are demonstrating that heat recovery can overcome these barriers. To name the ones selected by **EU-funded research results**:

- **Heat exchange technology** for commercial heat-to-power ORC systems for the cement, glass, steelmaking and petrochemical industries (TASIO project). This solution eliminates the intermediate heat transfer fluid of conventional ORC solutions.
- **Highly efficient heat exchangers** for thermal energy storage and reuse or commercialisation of waste heat (SUSPIRE project)
- **Thermal energy storage technology** based on phase change materials that can recover and store high-temperature heat, applied to furnaces (**VULKANO project**)

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Heat Recovery & Valorisation	
• **Innovative plug-and-play heat recovery** and conversion to power solutions with potential across a wide temperature spectrum, including novel supercritical CO2 cycle (i-ThERM project) • **Absorption Heat Transformer** that recovers low temperature heat and revalues it at competitive costs (Indus3Es Project) • **Innovative heat pump technology** that captures and upgrades heat energy from sewage system (LOWUP project) • **Heat pipes exchangers** to r**ecapture energy lost** from kilns and transfer to other processes (DREAM project) or heat pipe heat exchanger for **recovery of heat from exhaust streams** (ETEKINA project) • **Industrial heat pumps** that recover and reuse waste heat in industrial drying processes (DryFiciency project) • ReUseHeat EU project, **waste heat is revalorised with a heat pump and injected into district heating networks**. The source of waste heat comes from data centres (from the heat released to cool down the servers), hospital (from the cooling of surgery room and the areas with special air requirements), or metro (recovering heat from the tunnels). From the project, the main barrier encountered was that regulation and financial support is mostly missing in EU and therefore, it does not boost the promotion of waste heat investment. Plus, a contractual agreement is needed between the waste heat supplier and the district heating operator, which is not standardized and it needs one-to-one cooperation, which can hander the process.	
KEYWORDS	Heat recovery is directly related to solutions such as Waste Heat Recovery, Decarbonisation, Sustainable Industries, Synergies, Heat-to Power Solutions, Heat pipes, Absorption Heat Transformers, or Heat Pumps.
EXTERNAL LINKS	• Resource Pack on waste heat valorisation - Improving energy efficiency in process industries (CORDIS) • Handbook for Increased recovery of urban excess heat (ReUseHeat project)

Heat Recovery & Valorisation	
PRE-CONDITIONS & ENABLING CONDITIONS	Identification of best opportunities for heat recovery within a facility is not straight forward. Depends very much on: • Exergy balance: Available energy according to its temperature, flow, etc. will condition the potential of a waste heat from the technical point of view. • Temporal availability: Whether the availability is continuous or intermittent is an important pre-condition. • Expected paybacks. Financial viability and short paybacks (2-3 years) mark many of these projects. As enabling conditions, we can group them into two main categories: The first one, any enabler that would help solving technical feasibility. This would include not only the identification of best heat recovery opportunity but also the selection of the best suitable technology for the best business case. Within this group of enablers we can count assessment programs in energy efficiency, energy audits of industrial processes, etc. The second one is the group of financial enablers from subsidies to the recover heat to soft loans to finance the projects. In this second group we can also consider all necessary elements for the business case such as the presence of external operators, investors, etc.
CONSTRAINTS/ BARRIERS for implementation	Available waste heat is basically reused back into the same process or into the energy supply of the facility. Recovery for its valorisation outside of the facility presents several barriers (although some are also common to own valorisation in the facility): ***Physical barriers related to the site:*** There are barriers related to the available space for the recovery units, processes or the distance from the waste heat source and the heat sink.

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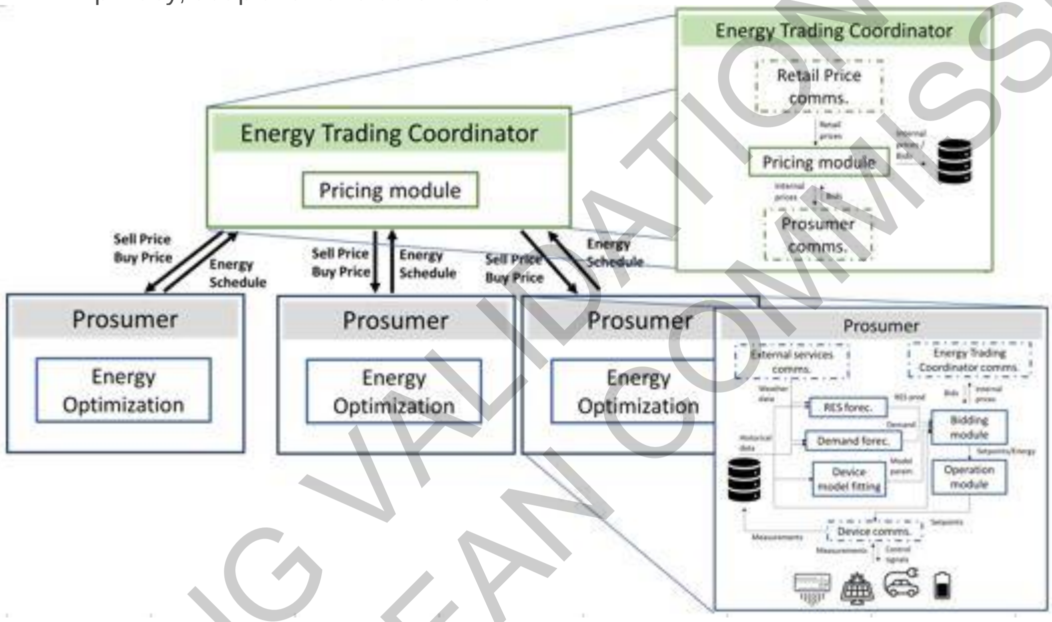
Heat Recovery & Valorisation	
	Low exergy heat: Not reused waste heat in the facility is, generally speaking, of low exergy and therefore its valorisation may be more difficult from the technical and financial point of view. ***Production cycles:*** Recovery must take into account the production cycle which also should consider shut downs due to maintenance or capacity. This generates difficulties in guaranteeing a continuous supply of the waste heat. ***External operators:*** Valorisation out of the facility usually requires an external operator (district heating operator for instance) that will take care of the valorisation. Agreement, considering technical and financial operation of the system between the parties involved will depend on the value proposition perceived by each party.
INSTRUMENTS/ Processes for implementation	Most interesting instruments are the ones that can help to finance the CAPEX and OPEX of these projects. From the list of instruments in NetZeroCities we can consider: • Loan for Energy Efficiency (https://netzerocities.app/resource-1648) to provide soft funding • Blended finance for Energy Efficiency (https://netzerocities.app/resource-1658) But it is also interesting to consider instruments related to planning where waste heat recovery from nearby industries or companies may be a renewable source of energy that should also be consider. For instance the following two instruments : • Integrated land use and urban planning with energy and climate (https://netzerocities.app/resource-1678) for introducing specific measures to foster waste heat recovery • Integrated climate plans for cities (https://netzerocities.app/resource-1698) for considering waste hear recovery & valorisation as a working line to explore.
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	After implementation there are not substantial adverse impacts as long as the production is not affected at the facility and the waste heat can be recovered as agreed (production changes may produce variations in temperature, flow rates, etc. that also changes available exergy). It will also require some additional maintenance that should be clear who must provide regularly
IMPACTS (Indicators & DNSH)	In terms of KPIs the most usual ones are related to the amount of energy provided through the valorisation of the waste heat. Will definitely vary upon its temperature, flow rate, recovery solution, user, etc. But there will be others related to business model behind the proposed solution to measure the performance of the system.
	From the point of view of DNSH principle it must be pointed out that this solution avoids substantial harms. Recovery of waste heat is a circular action that provides energy otherwise wasted and therefore reduces also the footprint. Furthermore, it develops a local solution that will improve local energy capacity. Due to the recovery systems, heat exchangers, piping, etc. metal production is the main source of emissions form a lifecycle point of view.
Additional information from CASE STUDIES	Waste heat valorisation: A thematic collection of innovative EU-funded research results: Waste heat valorisation (EC, 2020) and some Eu-funded projects as HEATLEAP, ReUseHeat, W.E. DISTRICT and LowUP.

3.4.2 Energy Management Systems

- Authors: **Tecnalia**
- Knowledge Repository link: https://netzerocities.app/resource-1408

Energy Management Systems
Energy Management System (EMS) is the powerful energy management concept that implies: • **Optimal integration of Distributed Energy Resources** (generation, storage a consumption with special relevance of renewable energy) in the energy system, especially in the distribution and transport energy grids. • The **emerging and active participation of new energy profiles** (active consumers, prosumers, aggregators...) in the energy framework, especially in the different existing and coming energy markets. • The **application of advanced and innovative technologies**, especially in the domain of the hybridation of energy vectors and in tech integration of intelligence to the energy management systems -EMS (artificial intelligence, algorithmic, data mining, blockchain...) to allow security, privacy, adaptation and automation.  EMS development are usually approached at **different levels**, basically: • The **integration of different energy resources**, specially generation and storage, and of different energy vectors (solar-wind-hydrogen, electricity-thermal, different forms of bioenergy...). • At the **energy systems level** being improved with remote monitoring and operation and automation capabilities enabling remote management and coordination with other systems. • At the **energy actor level**, specially, at the **prosumers** level as the owner of the energy system, providing them with smart tools for managing those energy systems dealing with their energy according to their strategies. • At the coordination level of the group of prosumers that form an **energy community** providing different services to those prosumer orchesting the exchange of energy between them, resolving the related exchange conditions, aggregating resources for the participating in energy markets, complementary services like traceability and registration, privacy, reference information (e.g. energy markets prices), etc.

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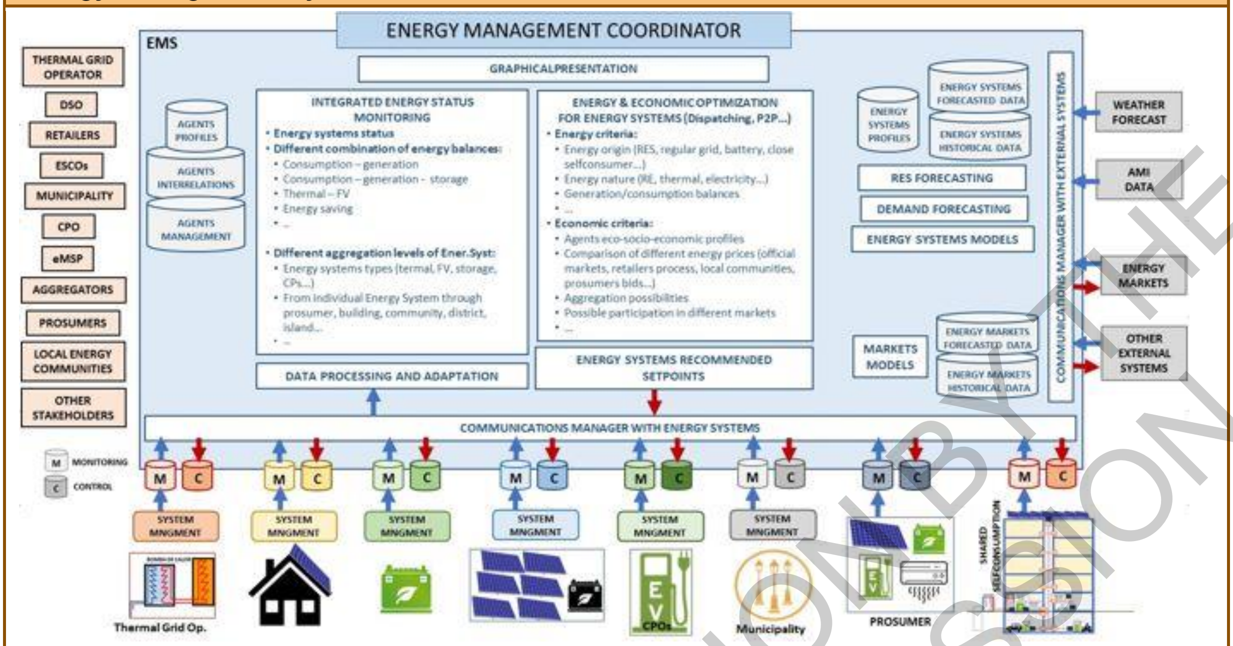
Energy Management Systems



CO-BENEFITS

The optimization of the energy generation/ storage/ consumption cycle at two levels, Prosumer level and Prosumer-2-Prosumer level, will allow the following co-benefits:

- **Reduce energy needs**
- **Increase access to clean, affordable, and secure energy**
- **Reduce GHG emissions**
- Social: **Enhancing citizen participation**, connectivity, and community

Energy Management Systems

PRE-CONDITIONS & ENABLING CONDITIONS

No specific predefined conditions must be met for implementing an EMS apart from some demand flexibility that is subject of a potential optimization. However, there are several factors that can influence the decision. Among other energy consumption, energy cost, regulatory requirements, environmental goals in the organization or the organizational culture for instance.

As enabling conditions we can consider on a non-exhaustive basis the following ones:

- Dedicated resources: Availability of dedicated resources such as staff, funding and technology is critical to its successful implementation. This includes hiring or designating an energy manager or team to oversee the EMS and ensure its effective operation (aggregator or a similar figure for example).
- Data Management: Accurate and reliable data is essential for effective energy management. Access to real time energy data should be foreseen and the ability to collect, analyse, forecast and report on energy consumption and costs across the organization.
- Performance measurement and reporting: Regular performance measurement and reporting may help to monitor progress, identify areas for improvement and communicate the benefits of the EMS to stakeholders. This must conclude on a continuous improvement of the tool.
- Training and awareness: Both programs are important to ensure that participants understand the value of the EMS and are equipped with the knowledge and skills to support its performance.

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<table>
<tr><th colspan="2">Energy Management Systems</th></tr>
<tr><td>CONSTRAINTS/ BARRIERS for implementation</td><td>As constraints or barriers to the implementation we can point out several ones but to group them somehow, we can consider:
Lack of resources:
This will be a common barrier to the implementation of any technology. Not only from the point of view of funding but also including staff and technology solution. The EMS requires upfront investment in hardware, software and personnel to set up and operate the system effectively. And this can become a barrier if the payback of the proposed solution is not very attractive.

Lack of data:
Without reliable data, it can be challenging to identify energy consumption patterns and implement effective energy optimization operations.

Resistance to change:
This is a significant social barrier, particularly in areas with entrenched practices and culture. Without buy in from stakeholders, prosumers, senior managers, etc., it can be challenging to achieve the necessary changes to support the EMS. We can connect this barrier with the lack of awareness on the benefits of this solution. Many times, due to being unaware of the potential financial and environmental outputs.

Complexity:
Implementation is often complex, involving multiple systems, data sources and stakeholders. Integration of existing systems into the EMS as well as managing the complexity of the EMS itself should be noticed.

Regulatory requirements:
While regulation can be an enabler it may also become a barrier if it is complex, unclear or onerous. Compliance with multiple, overlapping regulations can add extra complexity and cost.</td></tr>
<tr><td>INSTRUMENTS/ Processes for implementation</td><td>Most interesting instruments are the ones that can help to finance the installation of these solutions. From the list of instruments in NetZeroCities we can consider:
Loan for Energy Efficiency (https://netzerocities.app/resource-1648) to provide soft funding
Blended finance for Energy Efficiency (https://netzerocities.app/resource-1658)</td></tr>
<tr><td>DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation</td><td>There are not significant drawbacks or adverse impacts in the operation of this solution. However, its complexity may cause problems in its effective operation. For example, in the quality and or reliability of specific services. Or in the involvement of stakeholders and prosumers who may not perceive clear benefits on their participation.</td></tr>
<tr><td rowspan="2">IMPACTS (Indicators & DNSH)</td><td>From the point of view of measurement most common KPIs will take into account:
Energy consumption: As total energy usage, energy intensity (energy usage per unit of output) or energy cost
Energy savings: As total energy saved, energy savings as a percentage of baseline consumption or energy savings per unit of output
Greenhouse Gas Emissions
Cost savings
Etc.
But also, specific KPIs such as equipment uptime, reliability, maintenance cost, etc.</td></tr>
<tr><td>DNSH:
<table><tr><td>Climate change mitigation</td><td>This activity leads to greenhouse gas emission reduction on a lifecycle basis</td></tr><tr><td>Climate change adaptation</td><td>n.a.</td></tr></table></td></tr>
</table>

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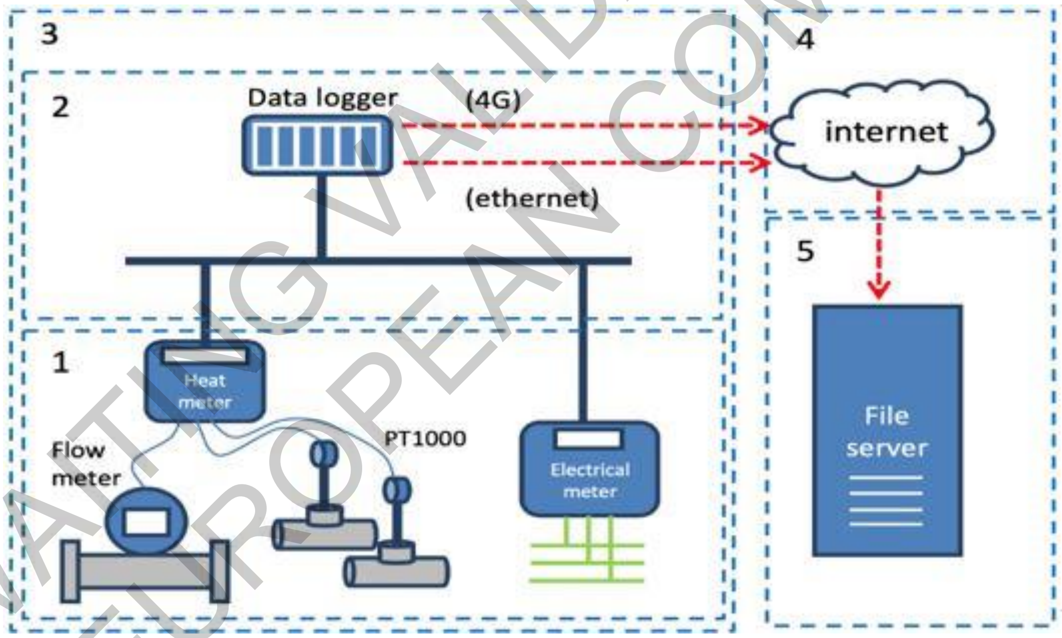
Energy Management Systems	
	Circular economy: The use of EMS will help a better use of generated energy. **Pollution prevention and control**: The EMS can help in pollution prevention and control.
Additional information from CASE STUDIES	• HOLISDER Integrating Real-Intelligence in Energy Management Systems enabling Holistic Demand Response Optimization in Buildings and Districts • https://eneuron.eu/ • https://www.deesme.eu/ • https://vicinity2020.eu/ • https://cordis.europa.eu/project/id/771066

3.4.3 Monitoring Systems

- Authors: **POLIMI**
- Knowledge Repository link: **https://netzerocities.app/resource-1418**

Monitoring Systems

The **monitoring system** is a time measuring tool aimed at monitoring, in the long term, the **impact of the energy system**. Thanks to the monitoring system it is possible to check the **energy and environmental performance** of the system collecting data such as water temperatures, water flow rates and energy consumptions. It allows also to verify the comfort conditions inside the building monitoring the inside air temperature.



*Monitoring system architecture, where: **1**=equipment; **2**=data logger; **3**=measurement tools, **4**=internet connection, **5**=server*

Through **data collection and analysis**, the monitoring system allows to:

- **quantify the energy used** for the different uses/ services, focusing in particular on those that most affect the overall energy consumption;
- characterize the **efficiency of generation system** and optimize the plant management; verify the achievement of the intervention targets;
- carry out **quality control activities**;
- **identify any improvement actions** to reduce energy and water consumption and improve comfort conditions;

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Monitoring Systems
• **assess the environmental profile** of the site in relation to environmental indicator CO2eq. Moreover, the monitoring system enabling the implementation of digital twin and gamification processes. **Digital twin** is a virtual model of the energy system installed and, together with a continuous commissioning, allows the optimization of the energy system even when the system changes with respect to the original project. **Gamification** aim is to engage and motivate final users through gaming techniques for a common goal: reduction of energy consumption.

CO-BENEFITS	The monitoring system allows a better control of the energy system with a consequent optimization of the plant efficiency. These actions lead to the **reduction of system energy consumptions** and the **decrease of the GHG emissions**. Moreover, a **raised awareness** on the building energy needs and system operation can be reached, allowing a **behavioural change** about the system use.
EXTERNAL LINKS	• Smart Cities Marketplace - Self-reporting tool • City Eye - a2a Smart City (Italy)

Monitoring Systems	
PRE-CONDITIONS & ENABLING CONDITIONS	Monitoring systems for energy performances is key to pursuit energy efficiency, indeed you cannot optimize what you don't measure. Usually, at least in the past, the energy system installer did not care too much to the actual energy performance of the system during operation phase, but just that the requested comfort is guaranteed. In order to change this practice policy can do a lot, requesting to the energy system installer to also monitor the actual system energy performance. Some EU directives (2012/27 and 2018/2002) already go in this direction, but it should be extended also to single family houses and to the other energy needs (i.e. space cooling and domestic hot water). From the social point of view the citizens should be aware of their energy consumptions and which are the most influencing factors in order to reduce energy waste.
CONSTRAINTS/ BARRIERS for implementation	From the economic point of view, the monitoring systems are becoming more and more cheaper, anyway they are not for free, in particular for water-based system, so for this reason the dissemination of cost-benefit analysis that highlights the advantages and potential energy and cost savings of monitoring systems should be empowered. From the technical point of view, there are already many good products on the market, but often the bottleneck is the lack of specialized installers that can handle it. Lastly, a key point for success is a comprehensive commissioning of the whole chain linked to a monitoring system. Indeed, as the monitoring system results has to be used to optimize the energy system control is key to have reliable measurements and data, so the sensors selection and installation should be carefully done, as well as the mapping of the logged measurements and the correct and optimal post-process of the logged data into data that can be easily interpreted and used by the final user and the HVAC system manager.
INSTRUMENTS/ Processes for implementation	The processes for the implementation are relatively easy for new buildings if the monitoring system is installed during the HVAC system realization. On the other hand, the installation of monitoring system on existing building is more complicated, in particular for water base system where there is the need to stop the system even temporarily and due some hydraulic works to install flow meters.
DRAWBACKS/ ADVERSE IMPACTS of the	This solution, if correctly installed, do not have any relevant adverse impacts as it is just a monitoring system, a passive system that does not do actions.

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Monitoring Systems	
solutions after implementation	
IMPACTS (Indicators & DNSH)	The impact of "monitoring systems" is mainly represented by: • The energy savings achieved by their use for the energy system control optimization • The improvement of the user comfort if not already achieved. OpenEnergy: smart meter: consume -3% of electricity, it gives you the opportunity to monitor monthly consumption and intervene on consumption management and budget optimization.
	The solution "monitoring systems" respect the DNSH principle (Do Not Significant Harm) as it is a passive system which does not need any particular harmful material.
Additional information from CASE STUDIES	As part of the so-called "scientific approach" everybody in the literature agrees on the usefulness of monitoring system. Below an example of a work based on the use of monitoring system is presented, but many other can be found in the literature. The scientific paper of Fumagalli et al. [1] describe a methodology and results of monitoring several heat pump systems installed in public buildings in the North of Italy. The three-year project, led by the Energy Department of Politecnico di Milano, aimed at evaluating the performance of heat pump systems on field; it involved several kinds of technologies, including gas driven absorption heat pumps. A new monitoring procedure, based on performance indicators expressed in terms of primary energy has been defined; the indicators are calculated on specific system boundaries, in order to characterize the performance of each meaningful subsystem of the monitored plants. Moreover, further indicators are defined in order to characterize the operating conditions of the system; through them, it is possible to understand the significance of the main performance indicators and detect possible faults in the design and management of the plants. The results of the monitoring of the five gas absorption heat pump plants are then presented. They highlight that the performance of a system is not determined solely by the efficiency of the heat pump, but depends also on the good integration of the machine in the system, that should be addressed at design level, and on the coherent management of the system. [1] Marica Fumagalli, Alessandro Sivieri, Marcello Aprile, Mario Motta, Matteo Zanchi, Monitoring of gas driven absorption heat pumps and comparing energy efficiency on primary energy, Renewable Energy, Volume 110, 2017, https://doi.org/10.1016/j.renene.2016.12.058.

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3.4.4 Replacement of equipment

- Authors: **CARTIF**
- Knowledge Repository link: **https://netzerocities.app/resource-1428**

Replacement of equipment
Replacement of equipment and machinery is defined as the "substitution of devices due to both economical operational cost reduction and/or the existence in the market of same kind of equipment with enhance characteristics", and not necessarily due to failures or existent damage. The main benefits of renewal of equipment are: • **Maintenance cost:** in general, maintenance and spare parts of old equipment increase along time in comparison with new devices, increasing the maintenance cost and reducing the competitiveness of the companies.

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<table>
<tr><th colspan="2">Replacement of equipment</th></tr>
<tr><td colspan="2">Increase in productivity: New equipment usually includes upgrade in the functionalities that improve the quality or reduce manufacturing time, increasing the productivity of the companies. These enhancements may include monitoring systems that can help to have a clear vision of the manufacturing process
Energy savings: According to the introduction of new energy efficiency policies, the energy consumption of new equipment is decreasing notably in comparison with old devices.
Recycling: The introduction of new equipment made under eco-design regulations contributes to circular economy increasing the ease of recycling and reuse of the materials.
A successful example is the case of electric motors and variable speed drives which, depending the kind of industry, may represent up to 70% of the energy consumed. Besides, the energy consumption of an electric motor represents 98% of its life-cycle total cost. The introduction of Regulation (EU) 2019/1781 laying down eco-design requirements for electric motors and variable speed drives fixes the minimum electric performance of this kind of devices. Following the policy mentioned, and according to real case studies, the renewal of old electric motors with new ones shows very low return on investment periods of about 2-3 years.</td></tr>
<tr><td>CO-BENEFITS</td><td>Renewal of equipment comes with remarkable reductions in energy needs, directly linked with reductions in GHG emissions. At the same time, the installation of new equipment decreases future maintenance costs in comparison with keep the old ones</td></tr>
<tr><td>EXTERNAL LINKS</td><td>Ecodesign requirements - electric motors and variable speed drives (EU Regulation 2019/1781)
Ecodesign requirements for energy-related products (Directive 2009/125/EC)
Impact analysis of carbon tax on the renewal planning of energy supply system for an office building
Energy Efficiency - Learn how you can save money: Calculate your Energy Savings</td></tr>
<tr><td>EXAMPLES</td><td>Renewable Energy Policies in a Time of Transition. Heating and Cooling. ISBN 978-92-9260-289-5. IRENA, IEA and REN21. Rabia Ferroukhi (IRENA), Paolo Frankl (IEA) and Rana Adib (REN21).</td></tr>
</table>

<table>
<tr><th colspan="2">Replacement of equipment</th></tr>
<tr><td>PRE-CONDITIONS & ENABLING CONDITIONS</td><td>Climate and geography:
The replacement of equipment in industry in general is not affected by climate or geography. However, in certain locations with extreme ambient conditions (high/low temperature, high humidity or coastal locations) the lifetime of the equipment is reduced significantly, increasing the need of foreseeing the ideal requirements for the new devices.

Technical aspects/infrastructure:
The presence of equipment manufacturers in the region, engineering companies with expertise in industrial maintenance and a reliable supply chain can promote the replacement of equipment.

Policy and regulatory/legal framework:
Subsidy schemes for small businesses focused on investments for replacement of equipment/appliances with more efficient ones. Regulations that ban the use of certain technologies such as coal boiler in industry.

Economic and social context:
Public awareness of the improvements derived from the replacement of the equipment.</td></tr>
<tr><td>CONSTRAINTS/ BARRIERS for implementation</td><td>Technical aspects/infrastructure:
The absence of local manufacturers of equipment, close contact from technical support or the need to buy them in other countries may hinder the adoption of new devices. In certain cases, the direct substitution of the equipment is not possible and new adaptations in the process or the building are needed. The latter may</td></tr>
</table>

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Replacement of equipment	
	affect the quality of products or services, or lead to a reduction in the production rate during or after the adaptation works ***Funding and finance:*** The absence of subsidies to replace the equipment for more energy and environmental efficient devices may increase the resistance of industries to replace them. ***Economic and social context:*** Inertia among consumers coming from lack of awareness about the benefits of adopting new technologies or low confidence in their overall potential. Consumer inertia with respect to transitioning may also be related to circumstances of distress, as when a boiler breaks down and owners tend to favour its replacement with the same technology. Besides, the cost of the new equipment and the investment CAPEX is higher than the repair of old devices.
INSTRUMENTS/ Processes for implementation	• User Engagement for Energy Performance Improvement https://netzerocities.app/resource-1498 • Cooperatives https://netzerocities.app/resource-1508 • Supporting municipalities to monitor resource flows in line with impact targets and measurement processes https://netzerocities.app/resource-1528 • Capacity building and engagement with municipalities to identify and co-create circular solutions and roadmaps https://netzerocities.app/resource-1548 • Capacity building and training https://netzerocities.app/resource-1578 • Educational/ Capacity building barriers identification https://netzerocities.app/resource-1588 • Loans for Energy Efficiency (EE) https://netzerocities.app/resource-1648 • Blended finance for Energy Efficiency (EE) https://netzerocities.app/resource-1658 • Decarbonisation Plans for Industry https://netzerocities.app/resource-1718 • Governance EU Climate Neutrality Framework https://netzerocities.app/resource-1728 • Turnkey Retrofit service https://netzerocities.app/resource-1843 • Circular Life Cycle Assessment/Analysis for material and products https://netzerocities.app/resource-1903 • User Engagement for Energy Performance Improvement https://netzerocities.app/resource-1498
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	Direct substitution of the equipment is often not possible and adaptations in the process or the building are needed. The latter may affect the quality of products or services, or lead to a reduction in the production rate during or after the implementation. New equipment may lead to misunderstandings in the manufacturing process New machinery with enhanced function may lead to a reduction in the number of jobs in the short-term because of automatization of repetitive tasks Training human resources is needed to use the equipment adequately, which is an additional cost for the company
IMPACTS (Indicators & DNSH)	• Circular economy. Benefits in the recycling of materials. Reduction of disposal costs. • Improvements in equipment management and flexibility • Updating of production processes • Installation of smart systems for monitoring and controlling energy consumption • Reduced equipment operating costs, better employee productivity with fewer emergency situations, and a better customer experience

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Replacement of equipment	
	• Opportunity for synergies between the deployment of technologies and public awareness activities

3.4.5 Solar Thermal in industries

- Authors: **REGEA**
- Knowledge Repository link: **https://netzerocities.app/resource-1438**

Solar Thermal in industries	
Solar heating technologies collect thermal energy from the sun and use this heat for drying purposes, for space heating/ cooling, or to provide process heat. With the advanced solar process heat technologies, **almost 50% of head demand in the industrial sector** could potentially be met. Heat in the **lower temperature** range (<80°C) can be provided with commercially available systems, such as flat plate collectors (FPC) and evacuated tube collectors (ETC). For **medium-temperature processes**, ultra-high vacuum FPC or ETC with concentrators can generate temperatures of up to 200°C. Solar concentrators like parabolic dish collectors, parabolic trough collectors, and Linear Fresnel collectors can generate compressed steam with temperatures of up to 400°C. Additionally, solar thermal-driven technologies can be used for **cooling or air-conditioning** purposes. The **costs** of solar heat for industrial process heat strongly depend on the process temperature level, demand continuity, project size, and the level of solar radiation of the site. The prices of solar heat projects are falling since 2010. In 2014, the weighted-average installed costs of 11 solar heat in industry projects were 1,679 USD/kW, while the average of 15 plants commissioned in 2020 dropped to 531 USD/kW, a decrease of 68%.	
CO-BENEFITS	Solar energy is a **clean, affordable, and secure energy**. By using solar thermal in industries, **GHG emissions** would be significantly **reduced** and therefore the **air quality** would be **improved**.
KEYWORDS	It is directly linked to Flat Plate Collectors (FPC), Evacuated Tube Collectors (ETC), on-site and nearby renewable energy generation (heat/cold).
EXTERNAL LINKS	• Renewable Power Generation Costs in 2020 (IRENA: International Renewable Energy Agency) • Cost trends of solar energy for heat in industry (Solar Payback) • Solar Heat for Industrial Processes - Technology Brief (IRENA: International Renewable Energy Agency)

Solar Thermal in industries	
PRE-CONDITIONS & ENABLING CONDITIONS	Deployment levels are mainly determined by the economic competitiveness of solar thermal systems. The majority of industrial heat demand (75%) takes place in large complex industrial sites. Although solar thermal energy could save costs in the long run, the complexities of integrating new heat sources into existing processes creates possible risks that the bulk producing industries try to avoid. One opportunity is to integrate solar thermal heating plants during the construction of new industrial plants. For small- and medium-size industrial plants, solar process heat could reduce the dependence on volatile fossil fuel prices. The key challenge is to maximise the share of heat provided by solar heating. This means that solar heating needs to be accompanied by storage to allow process heating during non-sun hours, storage for non-production hours, or more advanced control systems to optimise the usage of solar heating. For small- and medium-size enterprises, rooftop space and finance opportunities for the upfront costs are the key barriers

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<table>
<tr><th colspan="2">Solar Thermal in industries</th></tr>
<tr><td>CONSTRAINTS/ BARRIERS for implementation</td><td>Key challenges for solar thermal heat in industrial applications are:
Short pay-back times that are expected (< 3 years),
Relatively low fossil fuel prices charged in the industrial sector
Integration into existing industrial processes
The main barriers to increased deployment of solar industrial process heat and cooling systems are as follows:
High investment costs and lack of finance options
Fossil fuel pricing
Public awareness
Scaling issues
Lack of suitable design guidelines and tools</td></tr>
<tr><td>INSTRUMENTS/ Processes for implementation</td><td>Despite the technical potential, as well as the potential economic benefits of using solar heat in industry, actual deployment levels remain quite low. To achieve higher market penetration, policy options are: create more awareness of the benefits of solar process heating, especially in industrial clusters of small- and medium-size enterprises; provide financing mechanisms to cover upfront costs; and consider whether support for solar thermal could be an alternative to fossil fuel price subsidies to national industries.
Furthermore, solar process heat technologies can be supported by local manufacturing, as showcased in India, thus providing a mutually reinforcing strategy to support a healthy national industry.</td></tr>
<tr><td>DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation</td><td>There is a mismatch between the supply of solar irradiation and the demand for heat. For domestic hot water applications, during summer the discrepancy can be compensated with relatively small water storage to store the heat demand for about two days; however, if a seasonal mismatch must be offset, a very large storage volume will be required. Although technical solutions are available, such seasonal storage is currently only installed in pilot plants, since it increases the level of investment required and, consequently, the price of solar thermal heat rises significantly.

Solar thermal energy is often still not yet cost-competitive with fossil fuels at today's prices. The correct economic way to compare solar heat prices with those from fossil fuels is to calculate these over the lifetime of the solar thermal system. Then, competitiveness is strongly dependent on the assumed growth rate of fossil fuel prices.

In addition, a significant increase in public support programmes and budgets for research and development is needed, to stimulate the development of solar thermal technology with higher solar fractions, lower costs, and improved efficiency and reliability. In the long run, the combination of both, increased market stimulation and increased R&D will help solar thermal to become cost-competitive and an attractive heat source in Europe, without subsidies.</td></tr>
<tr><td>IMPACTS (Indicators & DNSH)</td><td>There are different factors that influence the environmental profile, including location, size, applied technology and materials (used for construction), water use, land use, operation and maintenance needs, etc.
Solar thermal is likely to be replacing gas, or possibly oil in rural areas, while solar PV will replace electricity.

The government figures for kilograms of carbon per kWh for each fuel type in 2021 can be seen below.<table><tr><td>Fuel type</td><td>Gas</td><td>Oil</td><td>Electricity</td></tr><tr><td>kgCO_2e per kWh</td><td>0.18</td><td>0.25</td><td>0.23</td></tr></table>
So, if we're replacing oil, solar thermal would lead to greater emissions reductions than solar PV but slightly lower if gas. However, it's a bit more complicated than that because of the continuing decarbonisation of the electricity grid as more</td></tr>
</table>

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Solar Thermal in industries	
	renewables replace other forms of electricity generation. By 2030 electricity is likely to have emissions of only 0.09kgCO_2e/kWh (according to government predictions) while the carbon emissions from oil and gas will remain fairly constant. Additionally, in the summer when the solar panels will be generating the most, the national grid has a lower carbon intensity anyway because of all the other solar PV that is plugged into it.
	DNSH: • Climate change adaptation • Transition to a circular economy • Protection and restoration of biodiversity and ecosystems
Additional information from CASE STUDIES	SEIA Case studies Matias, João & Saraiva, S. & Melicio, Rui & Catalão, João & Matias, J.C.O. & Cabrita, Carlos. (2011). Solar thermal system: practical case study. Link

3.4.6 High Temperature Heat Pumps

- Authors: **Tecnalia**
- Knowledge Repository link: **https://netzerocities.app/resource-1458**

High Temperature Heat Pumps
Heat Pumps are conversion devices able to transfer heat from a lower temperature heat source into a higher temperature heat sink. Within the last years, due to its large potential, its use for **industrial application**, recovering heat either from renewable sources or waste heat has been in the focus of the thermal sector. **Industrial waste** heat represents a valuable heat source for heat upgrade technologies due to its relatively high-temperature level in the form of, e.g. cooling liquid in refrigeration machines, wastewater, warm compressed air, or moist exhaust air. Overall, great application potential for **Industrial Heat Pump technologies** or **High Temperature Heat Pumps (HTHP)** has been identified for applications in the supply temperature range of 100 - 150°C in the food, paper, and chemical/pharma industries, in particular in drying processes, as well as in pasteurizing, sterilizing, evaporation, and distillation. On the other hand, steam is a commonly used form of energy in industrial process heating, especially in lower temperatures (<200ºC), being a significant amount of energy used in several industrial sectors, such as pulp & paper, food & beverages and chemical sectors.

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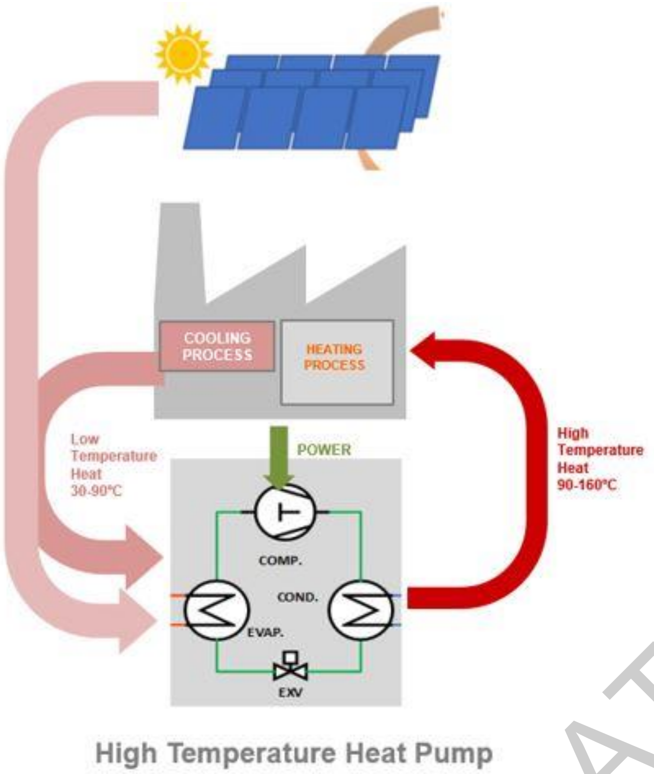
High Temperature Heat Pumps	
 The application of heat pump technologies opens additionally new options for **sector coupling** of electricity, heating, and cooling and provides flexibility, e.g. through heat storage in industrial plants. There are several available **HTHP technologies**, but each has its advantages and disadvantages. In particular, the degree of integration, e.g. at the process, utility, or supply level, affects the profitability and the ability to retrofit heat upgrade technologies in existing industrial plants. In recent years, there are several **start-up companies**, and customers are also willing/forced to switch from fossil fuel-based technologies to industrial heat pump technologies, but progress has been slow. Several heat pump manufacturers are beginning to offer products, but further development and demonstration are needed. Despite their efficiency potential and demonstration as a mature and efficient technology below 100°C supply temperature, industrial heat pump technologies have hardly been integrated into the industry for supply temperatures above 100°C.	
CO-BENEFITS	The use of High Temperature Heat Pumps upgrading low temperature heat sources (waste heat or renewables) contributes to the **increased access to clean, affordable, and secure energy** and **reduces GHG emissions**. Using Natural or Low GPW refrigerants also contributes to **reduce** the GHG emissions and the **energy needs** of the industry. Being the food sector one of the main potential users of this technology, it helps as well to have **sustainable and resilient food systems**.
KEYWORDS	HTHP are directly connected to solutions such as Waste Heat Recovery, Decarbonisation, Electrification, Sustainable Industries, Synergies, RES Heating and Cooling (heat pumps, solar, geothermal), Integration into 5G district heating and cooling networks. Additionally, it can be integrated into Power-to Heat-to Power Solutions.
EXTERNAL LINKS	• CHESTER Project: Compressed heat energy storage for energy from renewable sources

High Temperature Heat Pumps	
PRE-CONDITIONS &	There are several preconditions for the effective use of HTHPs. To name some of them:

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High Temperature Heat Pumps	
ENABLING CONDITIONS	• It is required an **adequate source and sink temperature**. The HTHPs operate more efficiently when there is a significant temperature difference between the heat source and sink. • Needs a **well-designed system** considering the application, temperature requirements, size and capacity of the system, refrigerant used, etc. • A **cost-effectiveness analysis** must be delivered to determine if the investment is justified based on the expected energy savings over the life of the system. This includes to calculate a payback and the CAPEX and OPEX to evaluate if economically is feasible for the industry. • HTHPs may be subject to **regulatory requirements** related to refrigerant use and emissions. Therefore, a regulatory compliance is a pre-condition. In terms of enabling conditions no need to mention **government policies and incentives**. For instance, tax credits, subsidies and regulations that promote the use of HTHPs. But also, awareness and training that can lead to a wider spread of this technology. For example, by fostering collaboration among industry stakeholders, promoting and sharing best practices, standards, etc. **Technological advancements** can also be a main enabler. Specially for achieving higher temperatures and using low GWP refrigerants.
CONSTRAINTS/ BARRIERS for implementation	Despite a great potential, persistent barriers and constraints appear for a wider use of HTHPs in industry. For example: • **Low level of awareness** on the suitability and potential of this technology among most of industries and solution providers. It is required advanced technical expertise to design, install and operate. • **Tailor-made designs** for its integration in industrial processes present higher cost than other technologies (i.e. gas boilers). • **Limited availability** of suitable refrigerants specially with higher temperature. • HTHPs **may not be adequate** for systems that require high levels of heating or cooling capacity because these may be beyond current capabilities of this technology. • There may be barriers at **regulatory level** due to the use of refrigerants. Their regulation may vary and its complexity may add cost to the implementation process. • **Payback periods** over 3 years that are larger than for gas boilers. • Although there are a number of commercial solutions, **few demonstrators** in the higher range of temperature can be found (between 130 ºC to 150 ºC).
INSTRUMENTS/ Processes for implementation	Most interesting instruments are the ones that can help to finance the installation of these solutions. From the list of instruments in NetzeroCities we can consider: • Loan for Energy Efficiency (https://netzerocities.app/resource-1648) to provide soft funding • Blended finance for Energy Efficiency (https://netzerocities.app/resource-1658)
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	As in any technology there are some drawbacks or adverse impacts in the installation and operation of HTHPs. Among others: • **Rise of electricity consumption** which if generated from non-renewable sources can offset the energy savings produced by HTHPs. • **Safety concerns** in some cases due to flammable, toxic of high GWP refrigerants. They can pose safety risks during installation, operation and maintenance. • **Maintenance and repair costs** may be higher than for other technologies (i.e. gas boilers) • **Installation complexity** also requires specific knowledge for operation and maintenance which may not be provided in-house and this may cause adverse impacts in production.

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High Temperature Heat Pumps	
IMPACTS (Indicators & DNSH)	Among others: • Energy consumption: As total energy usage, energy intensity (energy usage per unit of output) or energy cost • Energy savings: As total energy saved, energy savings as a percentage of baseline consumption or energy savings per unit of output • Greenhouse Gas Emissions • Cost savings • Etc. But also, specific KPIs such as equipment uptime, reliability, maintenance cost, etc.
	• **DNSH:**
Additional information from CASE STUDIES	• https://www.chester-project.eu/ • https://cordis.europa.eu/project/id/307169 • https://cordis.europa.eu/project/id/831062 • https://hpmoses2017.wixsite.com/hpmoses • https://cordis.europa.eu/project/id/101069689

Climate change mitigation	This activity leads to a significant greenhouse gas emission reduction on a lifecycle basis
Climate change adaptation	
Circular economy	Waste heat as a source provides a circular approach to the use of heat.
Pollution prevention and control	This activity leads to a reduction of consumption of fossil fuels, and consequently to a reduction of emissions. However, the use of some refrigerants may be harmful.

3.4.7 Green Hydrogen Technologies in green industry

- Authors: **CARTIF**
- Knowledge Repository link: **https://netzerocities.app/resource-1468**

Green Hydrogen Technologies in green industry
Green hydrogen refers to **electrolytic hydrogen** produced using electricity generated from **renewable energy sources**, and also to hydrogen produced via different methods using other renewable sources such as biogas, biomethane, bio-waste and other renewable sources. Since hydrogen's production translates into extracting it from its compound by using energy from other primary sources, it is an energy carrier used to move, store, and deliver energy.

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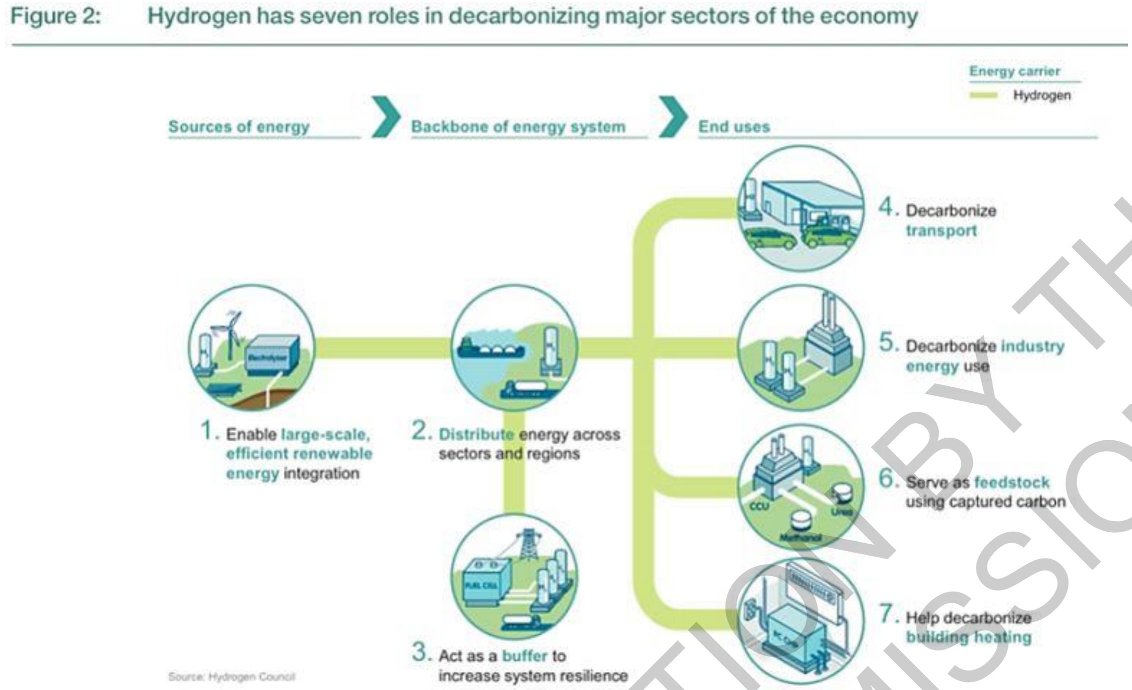
Green Hydrogen Technologies in green industry

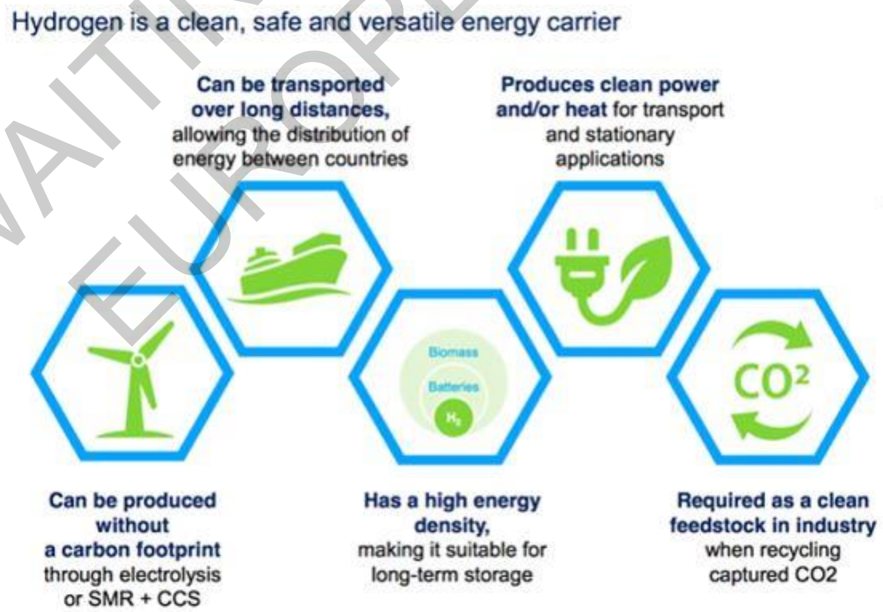


Source: Hydrogen Council (http://www.hydrogencouncil.com)

The **uses of the H2** can be grouped into two large categories:

- Hydrogen as a **feedstock in the chemical industry** (production of ammonia, fertilizers and methanol), as a reducing agent in the metallurgic industry, flat glass production, electronics industry, fuel production and electricity generation. Most hydrogen used in industry fits in this category.
- Hydrogen as an **energy vector**. The versatility of hydrogen and its multiple utilizations is why hydrogen can contribute to decarbonize existing economies. Hydrogen's role in the decarbonisation process can be summarized as shown in the graph below.

The use of H2 for electricity generations is **through Fuel Cells**. Fuel Cells are electrochemical devices which transform the chemical energy of the fuel oxidation reaction into electrical energy. The result of its use, apart from the power generations, is only the pure water that was originally used in its production and that can be recovered and reuse.



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Green Hydrogen Technologies in green industry	
The most important **hydrogen storage methods** include physical storage methods based on either compression or cooling. In addition, hydrogen can be stored using solids (Metal Hydrides), liquids, or surfaces. In terms of transportation, the most common means are compressed gas cylinders or cryogenic liquid tankers; pipelines or blending with natural gas. Renewable hydrogen is generally more expensive, although **prices** are becoming more competitive.	
CO-BENEFITS	**Reduce GHG emissions**, since the reaction do not produce CO2 and the Hydrogen is obtained using renewable sources. Due to the same reason, it increases **access to clean, affordable, and secure energy**. Hydrogen production is not restricted to certain countries, which means it can improve diversity of energy imports and improve energy security.
EXTERNAL LINKS	• An introduction to Fuel Cells - Status and applications of fuel cell technology, competing technologies & the market place (University of Birmingham) • Hydrogen Europe: https://hydrogeneurope.eu/industry/
EXAMPLES	• Japan: A success story in deploying Fuel Cell micro-Cogeneration (PACE Energy)

Green Hydrogen Technologies in green industry	
PRE-CONDITIONS & ENABLING CONDITIONS	***Climate and geography:*** The climatic and geographic conditions of a region can affect the efficiency and performance of Hydrogen Technologies. For example, extreme temperatures can decrease the efficiency of the electrochemical reaction inside a fuel cell, reducing the amount of electricity produced. Furthermore, the availability and cost of hydrogen in each region can also impact the feasibility and viability of using green hydrogen technologies on a large scale. Additionally, since the production of green hydrogen depends on the renewable generation and that, at the same time, depends on the climate conditions, the availability of hydrogen could be restricted in certain places or during certain seasons.[4] ***Technical aspects/infrastructure:*** Adequate and reliable sources of hydrogen, such as renewable energy or natural gas with carbon capture and storage need to be implemented. A hydrogen supply and distribution network, including pipelines, trucking, and storage facilities[5]. Technical standards and regulations that ensure the safety, reliability, and performance of fuel cells and hydrogen systems. In certain cases, DSOs and TSOs must approve the right to feed electricity into the distribution grid. ***Policy and regulatory/legal framework:*** Incentive programs and subsidies to reduce the upfront cost of green hydrogen technology and encourage adoption by consumers and businesses. Policies that support the development of a hydrogen infrastructure, including production, distribution, and storage facilities. Standards and regulations that ensure the safety, reliability, and performance of fuel cells and hydrogen systems. Programs and initiatives that promote research and development of fuel cell, electrolysers and green hydrogen production and storage technologies and support innovation in the field. Public education and awareness campaigns to inform the public about the benefits and potential of hydrogen use. ***Economic and social context:*** Competitive and affordable price for fuel cells and electrolysers technologies, adequate funding and support for research and development, and public education and awareness programs. In addition, it is important to have policies and regulations that promote the deployment and integration of hydrogen technologies

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Green Hydrogen Technologies in green industry	
	into the energy system, and to ensure that the benefits of using them are shared equitably among different social groups.
CONSTRAINTS/ BARRIERS for implementation	High cost of the use of hydrogen technologies compared to conventional energy management. This high cost is due to the high price of materials and the low production volume. With an estimated current hydrogen delivery price (including production, transportation and storage) of 5,3 EUR/kg, in order to achieve a break-even, the hydrogen delivery price would have to be below 3,0 EUR/kg – in a 'high energy prices' scenario and below 1,5 EUR/kg - in an 'adjusted energy prices' scenario. However, it is expected that a further decrease of the solar PV technology costs, coupled with a reduction in electrolyser CAPEX, resulting from scaling-up and automation of the manufacturing process, should lead to a significant fall in renewable hydrogen production costs in the coming decade. Electrolyser CAPEX alone, are expected to fall by around ¾ compared to current levels, enough to enable renewable hydrogen production costs with low-cost renewable energy,[1] Lack of infrastructure for the distribution and storage of hydrogen, and the cost of introducing a new infrastructure in parallel to gas pipelines adapted to hydrogen. The refurbishment of natural gas pipelines to make them available to transport hydrogen without the need of constructing new ones is still under research. When hydrogen production is based entirely on variable renewable energy, like solar PV or onshore/offshore wind, a significant amount of operational storage is needed. which is not uniformly available across the whole EU. Additionally, securing access to enough low-cost renewable energy is a challenge especially in the northern part of Europe. Lack of public awareness and understanding of hydrogen technologies, which can hinder the adoption of fuel cells by consumers and businesses. [1] Grzegorz Pawelec and Joana Fonseca, 'Steel from solar energy. A techno-economic assessment of green steel manufacturing', Hydrogen Europe, Jun. 2022. [Online]. Available : https://hydrogeneurope.eu/wp-content/uploads/2022/06/Steel_from_Solar_Energy_Report_05-2022_DIGITAL.pdf
INSTRUMENTS/ Processes for implementation	• User Engagement for Energy Performance Improvement https://netzerocities.app/resource-1498 • Cooperatives. https://netzerocities.app/resource-1508 • Capacity building and training https://netzerocities.app/resource-1578 • Educational/ Capacity building barriers identification https://netzerocities.app/resource-1588 • Loans for Energy Efficiency (EE) https://netzerocities.app/resource-1648 • Blended finance for Energy Efficiency (EE) https://netzerocities.app/resource-1658 • Integrated climate plans for cities https://netzerocities.app/resource-1698 • Decarbonisation Plans for Industry https://netzerocities.app/resource-1718 • Governance EU Climate Neutrality Framework https://netzerocities.app/resource-1728 • Circular Life Cycle Assessment/Analysis for material and products https://netzerocities.app/resource-1903 • Turnkey Retrofit Service https://netzerocities.app/resource-1843
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	High upfront cost: Green Hydrogen technologies are currently more expensive than other forms of energy generation, which can make it challenging for consumers and businesses to adopt. Decrease in the reliability of the equipment: Several low-TRL demonstration projects has shown issues in achieving operating hours at the final stack or short-stack sizes[1]. This problem could increase the

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	maintenance costs of the industries and reduce the reliability of the hydrogen equipment. The latter joined to the absence of a supply chain plan for the OEMs, may reduce the competitiveness of the companies. Dependence on hydrogen: Fuel cells rely on hydrogen as a fuel, which means that the widespread adoption of hydrogen could lead to increased demand for production and infrastructure. Safety concerns: Hydrogen is highly flammable and can pose safety risks if not handled properly. The large-scale deployment of hydrogen infrastructure could raise concerns about safety and accident prevention. Environmental impacts: While fuel cells do not produce greenhouse gas emissions when operating, the production of hydrogen from fossil fuels can result in emissions. The use of in critical raw materials such as platinum may pose an environmental threat due to the limited access and the hard conditions to get them[2]. In addition, the disposal of spent fuel cells can generate waste and pollution. Socioeconomic impacts: The deployment of fuel cells and hydrogen infrastructure could have impacts on the economy and society, such as job creation and displacement, and changes in energy pricing and availability. Regarding specific case studies: • **Ene.field project.** The project brought together European micro FC-CHP manufacturers to deliver and monitor trials across all the European domestic heating markets, dwelling types and climatic zones. The project found that the two main aspects to be improved in the installation of FC are the running costs and the ease of use of the technology. • **PACE-Energy project** is aimed to unlock the large-scale European deployment of Fuel Cell micro-Cogeneration in private home. In this case, the project found that the administrative procedure requested by some DSOs and TSOs may hinder the FCs implementation processes. [1] Clean Hydrogen Joint Undertaking, PROGRAMME REVIEW REPORT 2022. 2022. [Online]. Available: https://www.clean-hydrogen.europa.eu/document/download/32dd5caa-4fc5-4469-82a1-8079f85bcf43_en?filename=Programme%20Review%20Report%202022_1.pdf [2] Clean Hydrogen Joint Undertaking, PROGRAMME REVIEW REPORT 2022. 2022. [Online]. Available: https://www.clean-hydrogen.europa.eu/document/download/32dd5caa-4fc5-4469-82a1-8079f85bcf43_en?filename=Programme%20Review%20Report%202022_1.pdf
IMPACTS (Indicators & DNSH)	Applying hydrogen in heat and power can help regions increase their energy autonomy and reduce industry-related emissions of fine particulate matter and other pollutants. For mid and high-grade heat, biomass is an option, but in regions where that choice could face issues, hydrogen and electric heating are the only two low-carbon solutions for mid and high-grade heat. Hydrogen-based heating offers high flexibility and is thus well-suited for applications with intermittent heat demand.[1] [1] Hydrogen Council, 'Path to hydrogen competitiveness. A cost perspective', Hydrogen Council, Jan. 2020. [Online]. Available: https://hydrogencouncil.com/wp-content/uploads/2020/01/Path-to-Hydrogen-Competitiveness_Full-Study-1.pdf
	Regarding the implementation of Fuel-Cells: ***GHG savings:*** • 370 – 1100 kg CO_2 per kW of micro-CHP per year • Compared to a gas condensing boiler in a partially renovated semi-detached single-family home located in Germany, ene.field project found CO_2 emission savings by a generic FC-µCHP system of 33%. • Emission savings of between 45% and 50%, depending on the FC type, when the electricity production mix replaced is as carbon intensive as a

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Green Hydrogen Technologies in green industry	
	hard coal fired power plant and the heat-led FC-µCHP systems run up to 5333 full load hours per year • FC-µCHPs lead to 6-26% lower GHG emissions, 7-49% lower resource uses, 21-65% lower particulate matter induced impacts, 25-73% lower acidification impacts and 54-118% lower water uses. The upper values usually correspond to new buildings located in southern Europe (low heat demand), while the lower values usually correspond to existing buildings located in northern Europe (high heat demand). Regarding the implementation of RES and use of hydrogen technologies in isolated micro-grids or off-grid remote areas: • EUR 410 MWh unit cost for the hydrogen-based power-to-power solution over 10 years, compared to EUR 864/MWh for a new 20-km cable connection to the grid Regarding a methanol fuelled combined heat and power (CHP) production system based on high temperature PEM fuel cell technology[1] 2,600 €/kWh may be achieved [1] EMPOWER EU funded project. https://www.empower-euproject.eu/

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3.5 Circular economy

- **Knowledge Repository: Circular Economy:** https://netzerocities.app/resource-2615

Table 7: Circular Economy solutions

Circular Economy			Section
WASTE	Municipal solid waste (MSW)	Municipal Solid Waste separation at source: pay as you throw	0
		Municipal Solid Waste treatment: Anaerobic digestion for biogas production	3.5.2
		Urban biodegradable waste for compost	3.5.3
	Textiles	Circular textiles: Urban recovery and processing techniques, waste to feedstock optimization	3.5.4
	Electronics and ICT	Circular electronics and ICT: New processes & strategies for the recovery of Critical Raw Materials	3.5.5
	Batteries and vehicles	System level circular economy approaches in batteries	3.5.6
	Plastics	Plastic waste management	3.5.7
		Plastics: Expanding the use of bio-based and compostable materials	3.5.8
	Packaging	Circular packaging: Reducing demand for (over)packaging/ packaging waste, improved circular design and strategies that fully replace the need for packaging	3.5.9
	Construction and Buildings	Construction and Buildings: Optimal management of waste at the end of building life cycle	3.5.10
		Construction and Buildings: re-using local building waste	3.5.11
		Construction and Buildings: urban mining model to assess circular construction opportunities and optimize resource use and exchange	3.5.12
		Construction and Buildings: Residual Value Calculator	3.5.13
		Construction and Buildings: online register with building and infrastructure material/parts/products for reuse/circular use	3.5.14
		Construction and buildings: Circular Life Cycle Cost (C-LCC) for deep renovation	3.5.15
	Other waste products	Reduction of raw materials, waste and integration of secondary materials	3.5.16
WATER	Building level	Greywater and rainwater reuse at building level	3.5.17
		Efficient treatment and reuse of un-segregated water at building level	3.5.18
ENERGY	Energy Efficiency	Industrial symbiosis assessment and solution pathways for facilitating cross-sectoral energy and material exchange	3.5.19
	Energy Generation – RES	Production of biofuel based on black liquor from the paper industry	3.5.20
		Waste to energy in buildings	3.5.21
		Guarantee the energy saving/production in buildings: "Contingent approach"	3.5.22
FOOD		Circular Food Systems	3.5.23
		Encompassing the full value chain of producing food for human consumption – valorisation of low value fish species	3.5.24

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3.5.1 Municipal solid waste separation at source: pay as you throw

- Authors: **LGI**
- Knowledge Repository link: https://netzerocities.app/resource-2169

Municipal solid waste separation at source: pay-as-you-throw

Pay as you throw (PAYT) is policy instrument that charges citizens for the amount of waste they produce, so the Municipal Solid Waste (MSW) services are considered as an utility. It is often linked with the purchase of trash bags directly by the citizens, usually marked with a code.

Source: © 2014 WasteZero

There are different types of pay as you throw systems, with different outcomes and effectiveness.

- **Cash-based system**: Residents pay an amount in cash for every bag they dispose of at a convenience centre or transfer station.
- **Variable Rate Carts**: Residents choose from among different sizes of carts, paying more for the larger carts and less for the smaller ones.
- **Tags on Bags**: Residents pay by the bag by affixing a pre-paid tag or sticker to each bag of trash.
- **Bag-based system**: Residents dispose of their waste in specialized bags approved by the city or town and clearly marked with the municipal seal or other unique instructions/information; collection can be either with automated pickup or by hand, often this system works by trucks that weight the bags.

Where: smaller municipalities and metropolis.

Benefits: using economy to incentivise a less environmentally impactful lifestyle, great control over costs.

Win-win strategy that has conduct to high recycling rates in the cities where it has been implemented.

Product life cycle stages & Modules (EN15978): End of Life C1 – C4

CO-BENEFITS	Reduce ecological footprint, Green awareness, Better waste management, Promote the materials cycle, higher recycling MSW rates, reducing GHG emissions associated with making, distributing and disposing of products. Allowing economy to lead citizens action is an effective way to push for recycling and a more aware disposing.
KEYWORDS	Direct connection to solutions:

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Municipal solid waste separation at source: pay-as-you-throw	
	• Urban metabolism mapping: identifying product streams and material inputs (in addition to waste) • Circular Life Cycle Assessment/Analysis for material and products
EXTERNAL LINKS	• [1] https://greenbestpractice.jrc.ec.europa.eu/node/7 • [2] http://payasyouthrow.org • [3] https://residus.gencat.cat/web/.content/home/lagencia/publicacions/centre_catala_del_reciclatge__ccr/guia_pxg_en.pdf • [4] WasteZero. Save money. Reduce Waste. Pay-as-You-Throw for Kinston MA. 2015

Municipal solid waste separation at source: pay-as-you-throw	
PRE-CONDITIONS & ENABLING CONDITIONS	***Social context:*** Residents have to be aware of the benefits of the system and have the means to pay their waste production. The payment system must be as fair as possible and as simple as possible for every resident to adopt it. ***Policy and regulatory/legal framework:*** The legal framework needs to enable the implementation of pay-as-you-throw systems by removing flat rates on waste management and allowing for granular payment reflecting the amount of waste a household produces ***Project governance and implementation modalities:*** The local authority must be strong enough in resources and influence to be able to fully implement the system and limit the number of free-riders or non-compliers. ***User identification:*** Pay-as-you-throw systems implies that the waste management authority is able to identify who generates how much waste, which can be simple with individual containers but complex in case of collective containers.
CONSTRAINTS/ BARRIERS for implementation	***Maintenance*** Electronic Pay-as-you requires maintaining the electronic devices used to operate the system in the long-term. ***Complexity of multi-family buildings*** Knowing who generates how much waste can be hard to achieve in multi-family residential neighbourhoods.
INSTRUMENTS/ Processes for implementation	Instruments: Capacity building for city officials to understand urban metabolisms and circular solution opportunities Process: • Citizen participation • Communication • Test • Monitoring and control • Implementation schedule
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	Fraudulent behaviours Antisocial and fraudulent behaviours may appear, including illegal waste disposal, illegal dumps, and disposal of waste in neighbouring towns. This may be prevented by: 1. Having in place municipal ordinance that makes it easier to take measures against illegal waste disposal, which should be strictly applied, 2. Quickly cleaning-up places of illegal waste disposal, 3. Continuously providing residents information

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Municipal solid waste separation at source: pay-as-you-throw	
IMPACTS (Indicators & DNSH)	***Environmental Sustainability*** Increases in recycling and waste reductions, due primarily to the waste reduction incentive. GHG emissions (less manufacture, distribution, use, disposal. ***Economic sustainability*** Financing waste management expenses by generating revenue ***Equity*** Fairness by paying only for what is disposed by individual residents ***Smart bins:***

CARBON EMISSIONS ABATEMENT FROM CONNECTED CITIES[21] (tCO_2e/year)

	UK	Germany	Spain	France	USA	Europe
Connected Cities	435,000	498,000	226,000	383,000	1,990,000	3,018,000
Parking space monitoring	9,000	12,000	6,000	12,000	260,000	74,000
Smart bins	20	20	10	10	70	100
Street lighting	108,000	42,000	8,000	5,000	31,000	202,000
Traffic congestion management	38,000	61,000	40,000	45,000	212,000	403,000
Traffic congestion monitoring (road signs)	149,000	204,000	92,000	170,000	372,000	1,281,000
Traffic congestion monitoring (traffic lights)	131,000	179,000	81,000	150,000	1,116,000	1,057,000

Source: GeSI, Mobile Carbon Impact, 2016

Additional information from CASE STUDIES	Implementation guide for local authorities published by the Catalan Regional Waste Management Agency: Guide for the Implementation of Pay-As-You-Throw. Systems for Municipal Waste

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3.5.2 Municipal Solid Waste treatment: Anaerobic digestion for biogas production

- Authors: **LGI**
- Knowledge Repository link: **https://netzerocities.app/resource-2257**

Municipal Solid Waste treatment: Anaerobic digestion for biogas production
The **anaerobic digestion** of the organic fraction of municipal solid waste (OFMSW) is a common process implemented throughout the world as it offers a sustainable source of **biogas** while valorising municipal waste. Anaerobic digestion also produces **digestate**, a nutrient-dense mixture that can be used by farmers as a **high-quality fertilizer**:

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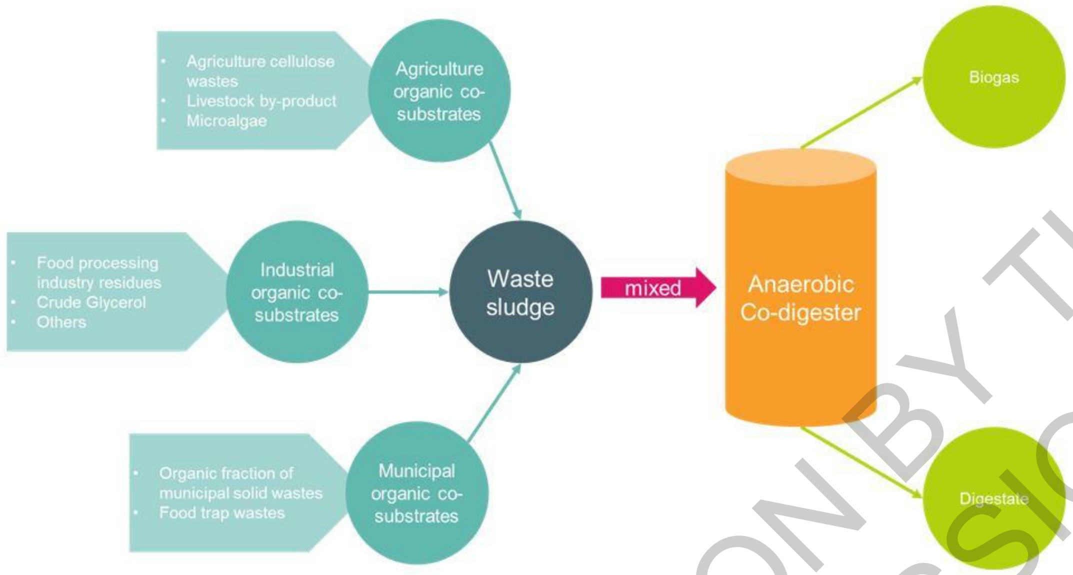
Municipal Solid Waste treatment: Anaerobic digestion for biogas production	



Anaerobic co-digestion is a variant of this process which refers to the mixing, digestion and treatment of two or more organic wastes in conditions of strict absence of oxygen. Among the potential organic wastes to be mixed with the OFMSW, the sewage sludge may be an attractive waste for sustainable management of two separate waste streams produced in large amounts in all countries. Anaerobic co-digestion allows for:

- The recovery of energy from different biomasses
- A higher methane production compared to single-feedstock digestion,
- A more efficient use of equipment,
- Costs reduction,
- A greater balance of nutrients,
- A greater degradation of organic waste.

Product life cycle stages & Modules (EN15978): C3 Waste processing to D Energy recovery

CO-BENEFITS	Increase access to clean, affordable, and secure energy, proximity economy, decrease future maintenance costs, Better waste management, Reduce GHG emissions, Increase access to clean, affordable, and secure energy.
KEYWORDS	Direct connection to solutions: • Municipal solid waste management and collection (district level): Smart waste: pay-as-you-throw • Urban biodegradable waste for compost
EXTERNAL LINKS	• https://www.sciencedirect.com/science/article/pii/S235248472031595X • https://www.researchgate.net/figure/Sources-of-main-organic-materials-in-anaerobic-co-digestion-of-WAS_fig3_336348438

Municipal Solid Waste treatment: Anaerobic digestion for biogas production	
PRE-CONDITIONS & ENABLING CONDITIONS	Legal authorization that allows biogas production through anaerobic digestion of organic feedstock Know-how and expertise that guarantees safety, maintenance, and the production of biogas in the long-term. Economic incentives that make biogas competitive in comparison with fossil fuels.

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Municipal Solid Waste treatment: Anaerobic digestion for biogas production	
CONSTRAINTS/ BARRIERS for implementation	***Technical barriers*** Infrastructural challenges Availability of feedstock type of feedstock Poor collection, improper segregation, a lack of vehicles and inadequate waste transportation Unavailability of local biogas technologies operator experience, skilled staff, and well-trained personnel Frequent need for repair and lack of attention paid to maintenance ***Economic barriers*** High investment costs Unavailability of bank loans with preferential terms High cost of managing and maintaining ***Market barriers*** Lower prices of fossil fuels and a high price of biogas ***Institutional barriers*** Lack of political support Policy landscape is very dynamic and uncertain A lack of private sector participation Poor coordination between the public and the private sectors ***Socio-cultural barriers*** Lack of public participation and consumer interest Low level of knowledge of the general population
INSTRUMENTS/ Processes for implementation	• Capacity building for city officials to understand urban metabolisms and circular solution opportunities • Gas grid standards • Goal on CO_2 emission reduction • Landfilling prohibition • Requirement on biological waste water treatment • Digestate certification • Fuel quality standard • Taxes and subsidies
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	Risk of GHG release if safe maintenance not guarantees Risks related to handling biogas
IMPACTS (Indicators & DNSH)	Volume of produced gas Volume of disposed industrial externality Share of biogas use Pulp and paper industry CO_2 emission reduction

3.5.3 Urban biodegradable waste for compost

- Authors: **METABOLIC**
- Knowledge Repository link: https://netzerocities.app/resource-2291

Urban biodegradable waste for compost
Urban biodegradable waste refers to waste from gardens and parks, food waste from households, restaurants, food services, and markets, as well as waste from food processing, excluding waste from

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Urban biodegradable waste for compost

forestry or agriculture, textiles, wood, or paper. Across the EU, between 118 and 138 million tons of biodegradable waste are generated each year, which makes up almost half of municipal solid waste. Urban biodegradable waste discarded in **landfills** poses a major threat for the environment as its decomposition releases harmful methane into the atmosphere.

To reduce the harmful effects of urban biodegradable waste, smart waste management is crucial. Currently only 40% of biodegradable waste is currently composted. However, composting offers a solution which cities can easily implement and which allows cities to recover high-quality secondary raw materials (composts and digestate). The nutrient-dense mixture can be used by farmers as a high-quality fertilizer. Using compost instead of chemical fertilizers not only reduces pollution but also produces healthier food. To successfully reduce the amount of urban biodegradable waste discarded in landfills, composting facilities or bins must be easily accessible to the population. Regulations such as municipal composting laws can help to accelerate large-scale urban composting.

To establish a more systemic way to manage urban biowaste, the deployment of **urban biorefinery** represents a more advanced but promising step for cities. The biorefinery represents a way to approach resource valorisation, aiming to use available renewable substrates (different urban biowaste stream, such as food, wastewater, or green waste) in order to provide high value marketable products while minimizing energy consumption and waste generation. Urban biorefinery has the advantage to 'cascade' biowaste through different processes (which may include anaerobic digestion and composting) and extract different valuable material (chemicals/pharmaceutical compounds, food compounds, nutrients) and energy products (bio-oil, biogas) and therefore optimize the management of waste.

Product life cycle stages & Modules (EN15978): D Reuse and Recycling

CO-BENEFITS	Smart waste management of urban biowaste can have several co-benefits: Reducing the waste ending up in landfills is essential to reduce GHG emissions. Next to this, a well-organized composting system can enhance citizen participation and helps to raise awareness/behavioural change. Using the nutrient-dense mixture produced from compost as a fertilizer also positively impacts local agriculture and helps to create a sustainable and resilient food system. It improves soil health, reduces the ecological footprint that conventional fertilizers have, and thereby contributes to greater biodiversity.
KEYWORDS	Direct connections: • Municipal Solid Waste separation at source (district level): pay-as-throw • Municipal Solid Waste treatment: anaerobic digestion for biogas production Capacity building: • Supporting municipalities to monitor resource flows in line with impact targets and measurement processes
EXTERNAL LINKS	• https://environment.ec.europa.eu/topics/waste-and-recycling/biodegradable-waste_en • https://www.unsustainablemagazine.com/urban-composting-is-an-idea-whose-time-has-come/

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Urban biodegradable waste for compost	
	• https://mdpi-res.com/d_attachment/sustainability/sustainability-12-04456/article_deploy/sustainability-12-04456-v2.pdf?version=1591088392 • https://www.oecd.org/environment/environment-at-a-glance/Circular-Economy-Waste-Materials-Archive-February-2020.pdf

Urban biodegradable waste for compost	
PRE-CONDITIONS & ENABLING CONDITIONS	***Funding and financing:*** Access to EU/national funding and innovation procurement can further incentivise the development of R&I solutions for circular design. For example Spain: Programa de incentivos a proyectos singulares de instalaciones de biogás | Idae ***Social context:*** Citizens, supermarkets, schools and businesses have to be aware of the benefits of compositing and separating their waste. Solely if they are informed about the benefits of composting will urban composting be effective. ***Policy and regulatory/legal framework:*** Municipal composting laws which accelerate large-scale urban composting and/or make composting mandatory. ***Project governance and implementation modalities:*** Citizen-engagement initiatives such as events, conferences, workshops, and stakeholder meetings to disseminate the project concept and activities are important to engage relevant actors, create new business opportunities, and maximise the chances of take up. Also informing the citizens when the municipal waste infrastructure has been updated (e.g. Valladolid sent to all citizens a letter informing about the new organic waste bins and provided a sticky info card to add to your home with information on recycling tips) ***Infrastructure readiness:*** Municipal waste infrastructure is capable to handle a newly separated stream of biowaste and have concrete outlooks of where the compost could be use/applied. Infrastructure: Access to markets for compost products, such as farmers, landscapers, and gardeners who can use compost to improve soil quality and productivity. ***Partnerships:*** Collaboration and partnerships among stakeholders, including municipalities, waste management companies, composting facilities, and community organizations, to support and promote urban composting efforts.
CONSTRAINTS/ BARRIERS for implementation	***Limited resources:*** Setting up large-scale composting pick-up and processing systems can be expensive and requires commitment of resources, people and land (source). ***Long duration:*** Composting can take a long time depending on the materials discarded on the compost pile. Some (household) wastes hold recalcitrant compounds and low nutrients, which make their composting difficult. When such waste is added in a composting pile, they slow down the composting rate of other materials. Composting is therefore not merely collecting green waste and discarding it together to create high-quality fertilizer, it needs to be monitored properly (Source). ***Public Buy-in:*** Ultimately, it is consumers that must bear the efforts of waste separation. Their level of engagement and education on composting rules will determine the success of a public composting program.

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Urban biodegradable waste for compost	
INSTRUMENTS/ Processes for implementation	• Training • Regulations for durability, reparability and recycling in public procurement • Awareness campaigns (e.g. Spain: DECOST raises awareness of primary schools' students on the benefits of organic waste composting) • Voluntary measures with stakeholders e.g. In Milan, to ensure citizen engagement, the city made sure to inform and involve citizens by designing a dedicated app. Furthermore, free vented kitchen bins were delivered to all households (source). • Taxation/Fines: E.g. Milan applies fines to the whole building for contamination of shared bins, and through this leverages social dynamics (neighbours applying pressure on one another to use the system correctly) to encourage good behaviour (source).
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	***Infrastructure/capacity***: A potential cluttering on public streets to accommodate new locations where to place biowaste for both private citizen and businesses ***Capacity***: Added stress/work on businesses that must now spend time on waste separation processes. ***Traffic***: A new rotation of waste pickup by trucks might need to be created for both private citizen and businesses adding pressure to congested city centres ***Odour and Pest***: Depending on the selection of waste bins, their locations, and the frequency of their pickup, the biowaste may emit odours and attract pests such as rodents and flies. ***Citizen awareness***: a barrier could be represented by consumers' inclination to dispose of waste in the easiest manner possible. People are often unaware of the meaning of compositing and/or do not take the time to separate their waste.
IMPACTS (Indicators & DNSH)	Citizen awareness/participation; Number of composting bins per citizen; (the amount of) smart solutions for waste management
	DNSH: Pollution prevention and control: Biowaste may, if not disposed properly, cause leakage, bad odours and/or nuisance from animals.
Additional information from CASE STUDIES	Recology: The Recology mission represents a fundamental shift from traditional waste management to resource recovery. We seek to eliminate waste by developing and discovering sustainable resource recovery practices that can be implemented globally. Bin-e: Bin-e is an AI-based smart waste bin, designed for public places, enabling them to simplify recycling. It sorts and compresses the waste automatically, controls the fill level and processes data for convenient waste management. Local urban compost pick-up programs.

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3.5.4 Circular textiles: Urban recovery and processing techniques, waste to feedstock optimization

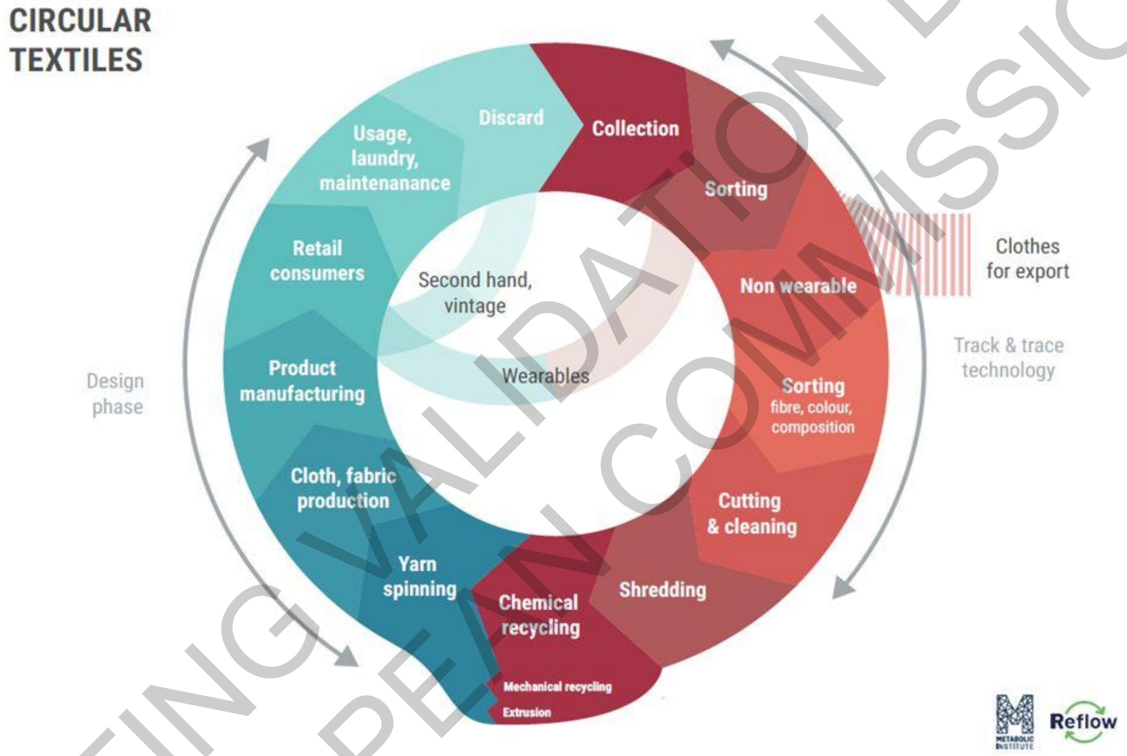
- Authors: **METABOLIC**
- Knowledge Repository link: **https://netzerocities.app/resource-2301**

This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

Circular textiles: Urban recovery and processing techniques, waste to feedstock optimization

Every year, up to 16 million tons of waste is generated by the textile industry in the EU, of which the majority is not recycled and ends up in landfill. Textiles made from natural or fossil materials require an intensive use of resources in production, leading to an increased need for circularity within the textile industry. Most commonly, recycling processes are focusing on the mechanical reuse of textiles. Turning textile waste into fibre using mechanical force often results in lower quality textiles that are often used as noise and thermal insulation materials.

However, research is exploring **innovative recovery and processing techniques** to unlock raw materials from collected textiles to produce **high-quality recycled fibres** from textile waste. Pilot projects such as the RESYNTEX research project are looking into the possibility of extracting resources from textile waste through chemical treatment. While mechanical textile recycling processes are cheaper and easier to perform and mainstream, **chemical processes** have the benefits of only producing small amounts of waste and being able to turn low-quality inputs into high-quality materials. However, the approach is also costlier and time-intensive and is expected to be scaled up only in the next 5-10 years.



Source: Metabolic Institute. Reflow Project
Product life cycle stages & Modules (EN15978): C1 Disassembling/ sorting + C2 Transport to waste processing + D Reuse and Recycling

CO-BENEFITS	• Valorising discarded textiles can increase waste efficiency and reduce waste that needs to be discarded in landfills. • Next to better waste management, reducing the demand for newly imported textiles can also reduce GHG emissions. • By locally recovering raw materials from collected textiles and using these materials to produce new textiles, the solution also boosts local business (km 0) and promotes a proximity economy. • Lastly, the techniques used require professionals to acquire new technological skills, which increases technological readiness and thereby also increases employment rate.
KEYWORDS	• Circular economy design principles to increase the durability, reparability, upgradability or reusability of products, in particular in designing and manufacturing activities • Supporting municipalities to monitor resource flows in line with impact targets and measurement processes

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This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

Circular textiles: Urban recovery and processing techniques, waste to feedstock optimization	
EXTERNAL LINKS	**EigenDraads Rotterdam**: • https://eigendraads.com/home-eng/ **Design for Decomposition project**: • https://d4d.biomimicry.org/ • REFLOW Amsterdam: https://reflowproject.eu/pilots/amsterdam/
EXAMPLES	Amsterdam Pilot (Reflow Project) Textiles is a critical and polluting industry since the Industrial Revolution – each year, 14,000 tonnes of textiles are thrown away in Amsterdam only. The Amsterdam Pilot will increase the recycling percentage of home textiles, through redesigning diverse methods for collection with citizens, while providing feedstock for the recycling industries. Jätehuolto city (LSJH), which is planning a processing plant for all of Finland's post-consumer waste textiles in the Topinpuisto circular economy centre. The facility will enable the recycling of post-consumer textiles, converting them into recycle fibre.

Circular textiles: Urban recovery and processing techniques, waste to feedstock optimization	
PRE-CONDITIONS & ENABLING CONDITIONS	***Funding and financing:*** Access to EU/public funding can be crucial to support the initial investment required to develop and/or purchase R&I solutions for circular textile design. Public funding needs to be coupled with private capital to ensure long-term economic sustainability, as technologies for innovating textile feedstocks and recycling entail long-term paybacks (source). ***Economic and social context:*** For commercialisation and take-up of circular design solutions for textiles, sufficient purchasing power is needed, both in B2B and B2C contexts, as circular business models tend to be at a competitive disadvantage compared to traditional ones (source). ***Policy and regulatory/legal framework*** Bans or restrictions on single use or non-recyclable materials: e.g. extended producer responsibility schemes (source). Project governance and implementation modalities ***Real collaboration:*** Business leaders across the value chain, investors, and leaders of public institutions would need to come together in an unprecedented way to engage in a highly operational joint effort to overcome the barriers to scale (source).
CONSTRAINTS/ BARRIERS for implementation	***Infrastructure*** Current recycling methods are not able to process all the types of current feedstock (a lot of recycling is actually downcycling). These methods therefore need to be innovated and upscaled to be able to process the feedstock that is available (e.g. separate mixed materials and remove dyes) (source). ***Economic challenges:*** The textile recycling industry faces economic challenges, such as competition from cheap imports and low prices for recycled materials. This can make it difficult for textile recycling businesses to be profitable and sustainable. ***Regulatory barriers:*** In some cases, local and national regulations may create barriers to the recycling of textiles. For example, regulations may require textiles to be cleaned or processed in a certain way before they can be recycled, or may restrict the use of recycled textiles in certain products. These regulations can add costs and complexity to the textile recycling process, making it less attractive to businesses and individuals.

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Circular textiles: Urban recovery and processing techniques, waste to feedstock optimization	
	Focus/investments Fashion brands are not motivated to invest in solving their biggest sources of environmental and social impacts. On the contrary, they are mostly investing in a specific type of (chemical) recycling which would only include a very minor part of their textile use (source).
INSTRUMENTS/ Processes for implementation	Training Material passports Certification and labelling: e.g. Extended Producer Responsibility for textiles Awareness campaigns
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	**Mixed textile waste:** post-consumer textile waste that is downcycled are typically blended materials, damaged, lack of quality, stained garments/uncleaned garments ("non-renewable PCTs) or market saturation from second-hand market and therefore hard to recycle into quality textiles Source). **Dyes and pigments:** post-consumer textile waste has different dyes, finishes and pigments that are hard to process and can have carcinogenic side-effects from (mechanical) recycling (Source). **Micro-fibre release:** Laundering, processing and recycling textiles releases micro-fibres into the environment which is detrimental to our health (source).
IMPACTS (Indicators & DNSH)	**Recyclability:** Textiles made from recycled materials have lower emissions than those made from virgin materials (Source) **Longevity:** Reducing new garment production by 5% through increased duration of first use, reuse, and repair could deliver environmental benefits equivalent to 20 tonnes of CO_2 emissions (Source)
Additional information from CASE STUDIES	CIRCTEX is focuses on the development of recycling and production technologies for PET workwear, such as innovative sewing threads and industrial microwaves for easy disassembly, to decrease non-renewable input materials and the ecological impact in textiles (Interreg North-West Europe, 2019-2022). Eigendraads is an initiative that started in Rotterdam to valorise valueless textiles. A growing share of discarded textiles no longer holds a value on the second-hand market. Based on an inventory of the characteristics of these valueless textiles, they map the challenge and explore potential solutions. While some of these valueless textiles can be turned into new yarn through mature technologies like mechanical recycling, a significant share of these textiles is left without a valuable destination, Eigendraads aims to tackle that.

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3.5.5 Circular electronics and ICT: New processes & strategies for the recovery of Critical Raw Materials

- Authors: **LGI**
- Knowledge Repository link: **https://netzerocities.app/resource-2315**

Circular electronics and ICT: New processes & strategies for the recovery of Critical Raw Materials
A variety of **new technologies and waste recovery systems** are being developed in response to European legislation and market forces that aim to recover critical raw materials (CRM) from end-of-life appliances. These diverse resource recovery processes are often regrouped under the concept of "**urban mining**", which considers cities' waste streams as economically important reserves of metals needed for digital and low-carbon technologies. Recycling **waste electrical and electronic equipment (WEEE)** has been gaining increasing attention as a potentially economically important

<table>
<tr><th colspan="2">Circular electronics and ICT: New processes & strategies for the recovery of Critical Raw Materials</th></tr>
<tr><td colspan="2">source of critical elements. Recycling WEEE avoids the environmental impact of landfilling hazardous materials while also reducing the need for primary extraction of critical materials, and the significant environmental damage extraction causes. Moreover, the EU is currently dependent on imports to supply much of it's required critical raw materials and harvesting from waste stocks thus helps mitigate the risk that supply could be disrupted.

The specific processing route for recycling can be based on pyrometallurgical (e.g., smelting) or hydrometallurgical (e.g., leaching) routes. The optimal choice will depend largely on the material properties of the element in question, its concentration in the feedstock, and its value as a commodity. For instance, Rare Earth Elements often have diffused uses in advanced technologies, making their recovery costly due to high energy or chemical inputs needed to concentrate them. Meanwhile, printed circuit boards can contain up to ten times the concentration of precious metals as geological deposits. The EU is placing a significant emphasis through updated legislation and innovation funding on developing and upscaling methods for recovering raw materials from lithium-ion batteries and permanent magnets. Effective recovery will depend on product design, standardization, and effective recovery mechanisms alongside technical processing at the end-of-life.

Product life cycle stages & Modules (EN15978): D Reuse and Recycling</td></tr>
<tr><td>CO-BENEFITS</td><td>Waste efficiency: Better waste management, Waste efficiency: Promote the materials cycle, Reduce ecological footprint, Raised awareness/behavioural change, Increase technological readiness.</td></tr>
<tr><td>KEYWORDS</td><td>Direct connection to:
• System level circular economy approaches in batteries
• Reduction of raw materials, waste and integration of secondary materials</td></tr>
<tr><td>EXTERNAL LINKS</td><td>• https://www.susmagpro.eu/
• https://www.orano.group/en/news/news-group/2021/july/orano-and-its-industrial-partners-launch-a-pilot-project-for-the-recycling-of-electric-vehicle-batteries
• http://www.urbanmineplatform.eu/homepage</td></tr>
</table>

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Circular electronics and ICT: New processes & strategies for the recovery of Critical Raw Materials	
PRE-CONDITIONS & ENABLING CONDITIONS	***Climate and Geography:*** The collection, sorting, and recycling of end-of-life products containing CRMs can take place in all European climates and geographies

This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

<table>
<tr><th colspan="2">Circular electronics and ICT: New processes & strategies for the recovery of Critical Raw Materials</th></tr>
<tr><td></td><td>Urban form and layout:
The separation of CRMs involving pyrometallurgical and hydrometallurgical processes can produce emissions that are harmful to human health and the environment, these activities require specific industrial zones. Dense urban forms can facilitate recovery of end-of-life products.

Technical aspects/ infrastructure:
Recovering and sorting end-of-life products requires significant infrastructure at the urban level. The refining of CRM's is also often technically challenging and energy/ chemically intensive, and will require major new investments to reach scale across Europe.

Policy and regulatory/ legal environment:
The EU Waste Framework Directive sets standards across member countries for waste treatment and incentivizes recycling where practicable. Efforts to recovery secondary CRMs will also be bolstered by the EU Critical Raw Materials Act which is expected to be ratified in 2023, with an emphasis on boosting domestic recycling capacities. The EU directives on batteries and waste electrical and electronic equipment (WEEE) also contain measures related to extended producer responsibility for end-of-life products that can promote the recovery of CRMs.

Funding and financing:
Funding for investments in the circular economy is available via numerous EU programmes including: Horizon Europe, Regional cohesion policy, the LIFE programme, and the Single Market Programme

Economic and social context:
High income countries consume more products containing CRMs, thereby generating higher secondary feedstocks of these materials. Moreover, successfully recovering end-of-life products from consumers requires socializing the general public to the value of the materials within the goods they consume, and raising awareness about the need to return these materials to producers.

Project governance and implementation modalities:
Active citizen engagement is key to ensuring proper recovery of CRMs from hibernating or end-of-life devices. Municipalities should also work with municipal waste collection services and private actors to ensure proper sorting and recycling facilities are available at the metropolitan level.</td></tr>
<tr><td>CONSTRAINTS/ BARRIERS for implementation</td><td>Climate and geography:
The collection, sorting, and recycling of end-of-life products containing CRMs can take place in all European climates and geographies

Urban form and layout:
Low density urban environments are correlated with higher costs of waste collection. However, it may be hazardous to process and recycle metals within close proximity to human residences.

Technical aspects/infrastructure:
Materials with a highly dispersed use, such as is typical of Rare Earth Elements and minor metals in specialty alloys, are very energy intensive to recover, making recycling cost prohibitive. Few companies in Europe have the technical capacity to separate and refine rare earth elements, and to perform other specialized refining processes such as refining battery grade metals.

Policy and regulatory/legal framework:
Large quantities of WEEE continue to be exported illegally out of the EU into jurisdictions with low environmental standards and recycling infrastructure. The</td></tr>
</table>

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Circular electronics and ICT: New processes & strategies for the recovery of Critical Raw Materials	
	stringent workplace exposure limits for many CRMs (such as cobalt) makes it challenging to operate recycling facilities for batteries within the EU. ***Funding and financing:*** Companies are reluctant to invest heavily in recycling facilities for many CRMs due to the long lifespan of many products containing them, meaning end of life battery or permanent magnet feedstocks will not become widely available for the next decade. As the materials used within state-of-the-art batteries and permanent magnets are rapidly evolving, there is little certainty of demand for recycled materials 10 years from now. ***Economic and social context:*** An economically viable recycling business must also confront highly volatile global commodity markets, that will cause instability in their profitability. Consumers also lack knowledge of how best to return their CRM containing products at end-of-life, leaving many materials in hibernation. ***Project governance and implementation modalities:*** The logistics related to effective collection and sorting of CRM containing materials continue to be a major challenge limiting their effective recovery.
INSTRUMENTS/ Processes for implementation	• Supporting municipalities to monitor resource flows in line with impact targets and measurement processes • Capacity building and engagement with municipalities to identify and co-create circular solutions and roadmaps • Capacity building for city officials to understand urban metabolisms and circular solution opportunities • Urban metabolism mapping • Circular Life Cycle Assessment/Analysis for material and products
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	For certain particular materials, recycling may have a higher emissions footprint than producing primary material (depending upon the metallurgical route chosen in each scenario). Recycling can also produce negative local effects including the discharge of GHGs and other harmful pollutants into the air from smelters, or the possible discharge of hazardous chemicals (such as strong acids) from hydrometallurgical plants.
IMPACTS (Indicators & DNSH)	GHG emissions avoidance (e.g., by removing the need for energy consumption or by reducing the trip length) (%CO2e) Total capital requirements per unit of output (EUR/unit) Total annual operational costs per unit or per energy output (EUR/unit or EUR/MJ)

3.5.6 System level circular economy approaches in batteries

- Authors: VTT
- Knowledge Repository link: https://netzerocities.app/resource-2383

System level circular economy approaches in batteries
The transition to a **low-carbon economy** will lead to an exponential increase in demand for **batteries and raw materials for batteries** (such as lithium, cobalt, nickel and manganese) - this supply risk could at least partially be reduced by **system level circular economy (CE) approaches**. CE is an economic system in which life cycle thinking, sustainability, systems thinking are at the core. CE concept aims to keep materials in use and design out waste and emissions by using recycled and secondary raw materials, by extending the lifetime by promoting the durability extension, removability

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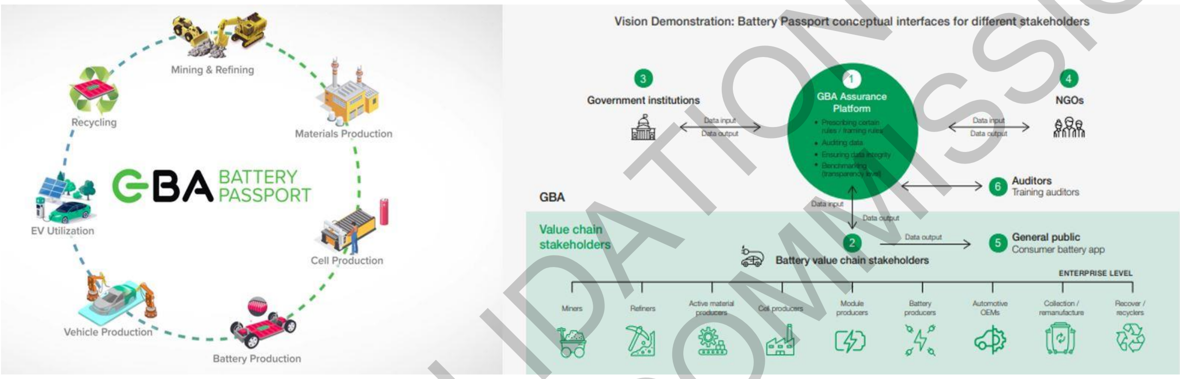
System level circular economy approaches in batteries

and replaceability, and where feasible the repair and reuse of batteries and finally by recycling battery raw materials and recovering valuable elements. From CE point of view, recycling and recovery of battery raw materials are not enough, and innovations based on **materials substitution, materials and products re-design** can change materials requirements substantially.

"**Design is the key**": up to 80% of product's environmental impacts are determined at the design phase. This gives the opportunity adopting circularity and sustainability aspects as design criteria's already in development of battery materials, battery designs and processes to achieve higher levels of circularity and reduce the environmental impact. Holistic perspective and system-level approach is needed for system optimization with respect to multiple objectives.

One example of practical means in this is **Digital Battery passport** - a digital tool to improve circularity and sustainability. The concept of a battery passport was initially presented by the Global Battery Alliance (GBA). The GBA Battery Passport will be a digital twin of a physical battery. Basically, it will be a sustainability certificate that contains all applicable information on environmental, social, governance, and life-cycle requirements involving all actors in the battery value chain:



Source: Global Battery Alliance. https://www.globalbattery.org/battery-passport/

Target audience: Battery value chain actors, Battery material, product and process designers, Consumers.

Product life cycle stages & Modules (EN15978): A1 Raw materials supply

CO-BENEFITS	• Increase access to clean, affordable, and secure energy • Promote the materials cycle • Reduce ecological footprint
KEYWORDS	Direct connection with solution: • Circular electronics and ICT: New processes & strategies for the recovery of Critical Raw Materials • Reduction of raw materials, waste and integration of secondary materials • Circular economy design principles to increase the durability, reparability, upgradability or reusability of products, in particular in designing and manufacturing activities
EXTERNAL LINKS	• https://www.globalbattery.org/media/publications/wef-gba-battery-passport-overview-2021.pdf • https://www.youtube.com/watch?v=-9xHRXSAN9I

System level circular economy approaches in batteries	
PRE-CONDITIONS & ENABLING CONDITIONS	***Technical:*** A battery passport that provides relevant life cycle information would enable **value chain actors** to use the information in **design-related decisions** to improve the sustainability and circularity of batteries.

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System level circular economy approaches in batteries	
	Legal: The European Commission has proposed a new Batteries Regulation which aims to modernize the EU's legislative framework for batteries being an integral part of the European Green Deal and the first initiative of the European Commission on the Circular Economy Action Plan. Article 65 in new Batteries Regulation covers the Battery passport, stating that each electric vehicle battery placed on the market shall have an electronic record "battery passport". Regulation aims to ensure that batteries placed in the EU market are sustainable and safe throughout their entire life-cycle by establishing mandatory requirements for batteries placed on the EU market. ***Economic:*** Battery passport truly creates value for battery value chain actors and can be used to support decision making to improve sustainability and circularity of batteries.
CONSTRAINTS/ BARRIERS for implementation	***Technical:*** Lack of solutions and agreements for information and data sharing about materials, components and products that allows for tracking the value chain, lack of data and tools and methods to analyse data in a consistent, holistic and comparable manner. Technical issues related to the prevention of data tampering and secure sharing of sensitive data need to be solved. ***Legal:*** Inefficiently coordinated policy and regulatory framework. Issues related to extended producer/manufacturers responsibility. ***Economic:*** Battery passport does not create value for companies and just increases the burden of bureaucracy. Market will not be able to bear the additional costs of the materials and products due to the necessary investments.
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	***Technical:*** The key questions that need to be solved in the implementation of a battery passport are related to where the data is stored, who has access to the data, how the data are analysed, and what are the key performance indicators and how they are calculated. Batteries should be designed for reuse and recycling and have sufficient history information to identify battery safety and chemistry for sorting. The operating history or remaining useful life of large battery systems should be shared to assess the profitability and safety of potential reuse. Economic: Battery passport works only as a legislative obligation, and do not create any value for battery value chain actors.
Additional information from CASE STUDIES	Battery Passport, (Global Battery Alliance, 2020), also video link.

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3.5.7 Plastic waste management

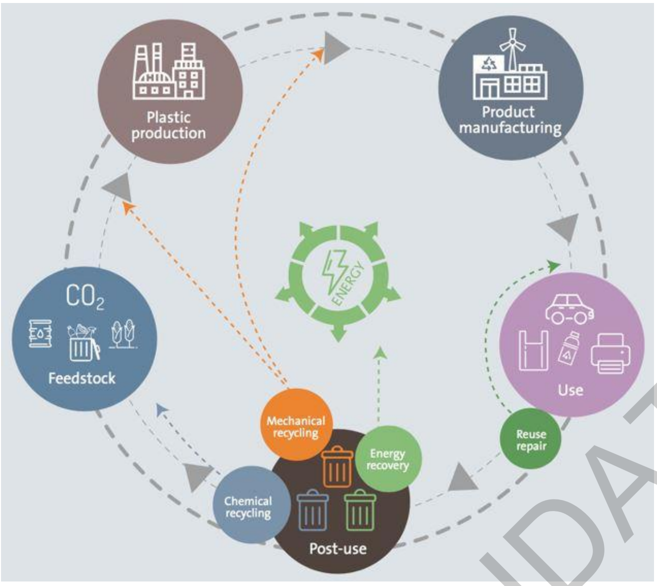
- Authors: **LGI**
- Knowledge Repository link: **https://netzerocities.app/resource-2421**

This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

Plastic waste management

Plastics are among the key sectors identified in the EU Circular Economy Action Plan. The need for solutions that promote circularity in this sector will be increasing as their consumption is expected to double in the coming 20 years.

Plastic Waste Management refers to the **prevention, reuse, recycle, recovery and disposal** of plastic waste generated by households and companies in an area. Recycling plastic material refers to the process of recovering waste or scrap plastic and reprocessing materials into functional and useful products. It is important to distinguish different types of plastics in this context:



Source: Woldemar d'Ambrières, « Plastics recycling worldwide: current overview and desirable changes », Field Actions Science Reports, Special Issue 19 | 2019, 12-21.

The benefits of plastic waste management are

- putting less pressure on virgin materials,
- giving new life to old plastic products
- shifting from polluting practices to a circular economy.

Product life cycle stages & Modules (EN15978): C1 – C4 End of Life

CO-BENEFITS	• Waste efficiency • Better waste management • Promote materials cycle • Greater biodiversity: reduce ecological footprint by reducing soil, water and air pollution • Climate mitigation Reduce GHG emissions both in oil production, raffination and burning plastic
KEYWORDS	Direct connection with solutions: • Expanding the use of bio-based and compostable materials, sustainably sourced bio-based • Reducing demand for (over)packaging/ packaging waste, improved circular design and strategies that fully replace the need for packaging • Reduction of raw materials, waste and integration of secondary materials • Circular economy design principles to increase the durability, reparability, upgradability or reusability of products, in particular in designing and manufacturing activities
EXTERNAL LINKS	• [1] https://www.sciencedirect.com/science/article/pii/S2666016421000645 • [2] https://www.oecd.org/newsroom/plastic-pollution-is-growing-relentlessly-as-waste-management-and-recycling-fall-short.htm

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Plastic waste management	
PRE-CONDITIONS & ENABLING CONDITIONS	***Plastic waste characteristics*** Mixed plastic waste is heterogeneous in composition and quality. The treatment (technologies) of plastic vary between plastic types (polymers). Thus, a pre-condition for plastic recycling is a sorting system that allows for homogenization of the waste stream. ***Waste sorting*** A sequence of sorting steps needs to be implemented in order to treat plastic waste, either manually or optical, that homogenize the feedstock and eliminate foreign materials. ***A functioning value chain*** Plastic waste management implies having a function management infrastructure from collection to recycling to repurposing and distribution.
CONSTRAINTS/ BARRIERS for implementation	***Policy barriers*** • Misalignment of regulations • Financial stimulation • Minimum recycled content • Public awareness • Lack of enforcement of waste legislation ***Economic barriers*** • High costs of recycling • Price competitiveness of recyclate • Fluctuating costs • New markets and applications • Increased prices for consumers • Costs for research and development • Reluctance to invest in more expensive recycling methods • Lack of economies of scale for new investments • Investment costs for capital and infrastructure • Supplier transaction costs • Long-term contracts for more security of investments • Growing demand from existing markets ***Technical barriers*** • Heterogeneous waste streams • Lack of infrastructure for separate collection and recycling • Hazardous additives in plastics, such as flame retardants and plasticizers • Lack of efficient sorting technologies for homogenization of the feedstock • Processing requirements for using recyclates differ from requirements when using virgin plastics ***Cultural barriers*** • Internal organisation and decision making • Consumer demand and acceptance • Resistance to change • Lack of knowledge, information and education
INSTRUMENTS/ Processes for implementation	• Supporting municipalities to monitor resource flows in line with impact targets and measurement processes • Capacity building and engagement with municipalities to identify and co-create circular solutions and roadmaps • Educational/ Capacity building barriers identification • Circular economy design principles to increase the durability, reparability, upgradability or reusability of products

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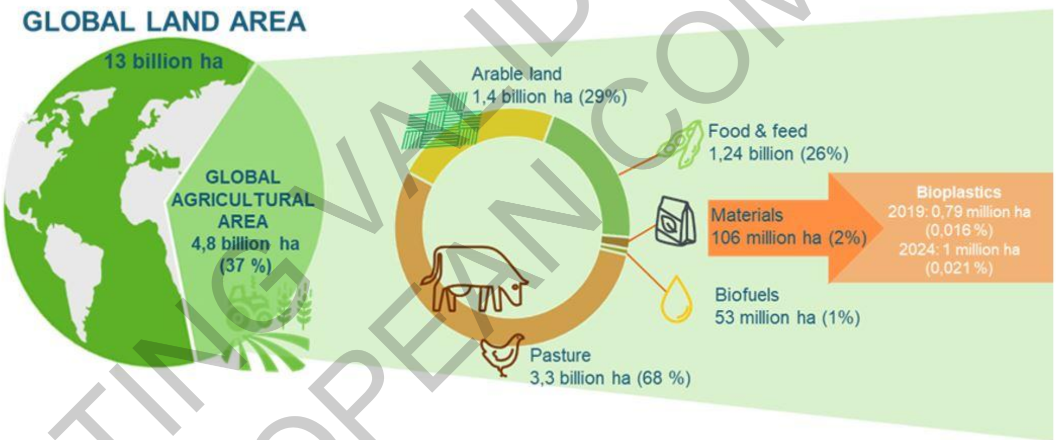
Plastic waste management	
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	• Dependency on waste generation • Maintenance and operational costs
IMPACTS (Indicators & DNSH)	• the annual or monthly production of waste (in kg or liter) • annual or monthly production of recycled products • annual or monthly costs for waste management • the number of collections detected

3.5.8 Plastics: Expanding the use of bio-based and compostable materials

- Authors: **VTT**
- Knowledge Repository link:

Plastics: Expanding the use of bio-based and compostable materials
Currently, the share of the **bioplastics** from the overall global plastics production is only 1% (2.1Mt), and it is applied largely for packaging solutions. Globally, sustainability strategies of different countries include replacement of fossils with renewables, however, this intended increase in biomass use will potentially lead to trade-offs that need to be studied. In 2019, material use took up to 2% of global agricultural area, from this share bio-based plastics covered approximately 0.016%:



Source: European Bioplastics 2019

Based on estimations if all global fossil plastics are to be produced from biomass, the demand for feedstock would grow to 5% of the total amount of biomass produced and harvested each year. The figure does not account for the use of side and waste streams. Subsequently, this increased share competes with other uses of land such as Food & Feed. When the projections for global food increase are considered, the sources for bio-sourced plastics should be focused on the utilization of side and waste streams, and wood biomass from forests. But as forests act as a carbon sink, their use to respond to the global biomass increase is cumbersome. Forests as source of **biomass** already have **competing applications,** such as for construction, different materials, and energy generation. In addition, forests as a source of fibre are seen as a solution for instance also in textile sector to replace emission intensive materials such as cotton (requiring vast amount of water, pesticides, fertilizer and arable land). Thus, the capacity of different biomasses in the production of plastics should be assessed from the **sustainability perspective** to ensure which applications are the most impactful ones for mitigating the climate change and reducing the environmental impacts. At same time, in driving the use of bioplastics, it is crucial to note the difference in bio-based materials and biodegradable materials

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Plastics: Expanding the use of bio-based and compostable materials	
– bio-based materials do not mean that the material is biodegradable. Bio-based solution does not necessarily ensure circularity. **For the municipalities**, the critical issue is to solve how the material can be **recycled back into materials without losing or minimizing its value**. For instance, **biodegradability** should be taken into account from the function aspect, as the feature is not always necessity for every application. In design, bio-based and biodegradable products should be aimed at re-circulation, although for each application the expediency of different circular economy strategies should be evaluated carefully. *Product life cycle stages & Modules (EN15978): A1 Raw materials supply*	
CO-BENEFITS	• Climate mitigation: Reduce GHG emissions • Waste efficiency: Better waste management • Waste efficiency: Promote the materials cycle
KEYWORDS	Direct connection with solutions: • Plastic waste management • Reducing demand for (over)packaging/ packaging waste, improved circular design and strategies that fully replace the need for packaging • Reduction of raw materials, waste and integration of secondary materials • Circular economy design principles to increase the durability, reparability, upgradability or reusability of products, in particular in designing and manufacturing activities

Plastics: Expanding the use of bio-based and compostable materials	
PRE-CONDITIONS & ENABLING CONDITIONS	***Political & legal:*** The challenges and growing understanding of the implications of plastics has led to a change in the regulatory framework. For instance, EU has set ambitious policy measures and targets for all the packaging to be 100 % recyclable, reusable or compostable by 2030 in the EU (European Commission, 2019). In addition, EU has established recycling targets for plastic packaging: 55 % by 2025, 60 % by 2030 and 65 % by 2035 (European Commission, 2018). The climate neutrality targets will have an inevitable effect to plastics value chain, where the use of renewables is seen as one of the key solutions. ***Economic:*** To drive the transition, intense investments are needed in R&D and infra to back the circularity of plastics, including bioplastics. Technical: Current plastics waste consists of a heterogenous mixture of packaging waste, which causes challenges to the production of high value and quality recycles. The typical recycling infrastructure is vastly based on a manual identification and separation, whereas the refining of a more valuable products requires forceful investments in R&D and infra (such as smart sensor-based separation processes) to support circularity.
CONSTRAINTS/ BARRIERS for implementation	***Political & legal:*** As the majority of bioplastics is used for packaging, such a food packaging, efforts should be put on improving their circularity. For instance, EU legislation on food packaging sets strict conditions for the recycling, first-hand requiring the use of virgin materials as contact materials in food applications (European Commission, 2008). Safety as cornerstone in food sector cannot be jeopardized, thus calling for R&D&I to develop the means to process food packaging waste back to useful use. Bioplastics, compared to fossil-based plastics, which have been developed and researched for a long time, need vast research to drive their optimal use. ***Economic:*** Plastics have been designed first-hand for a linear economy emphasizing single use and low-cost production. They can be used for versatile applications enabled by characteristics such as light weight and easy modulability for different use, making their mass production effortless. Technical: The variety of plastics materials

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Plastics: Expanding the use of bio-based and compostable materials	
	is massive and this makes the establishment of functioning circular loops extremely challenging. For the starter, there is a lack of infrastructure for collection and processing of different plastics, and furthermore, the markets for recycled polymers is still in its infancy.
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	***Technical***: Although bio-based plastics are designed for recycling, they are not made use of at the end of life due to insufficient capacity in volume.
IMPACTS (Indicators & DNSH)	Monitoring the GHG emissions of the plastics life cycle is essential. The GHG emissions from plastic production and incineration are more than 850 million metric tons, which is equal to the emissions from 189 (500 MW) coal power plants and nearly as much as the total GHGs of Germany in 2019. Based on current projections by 2050 the cumulative emissions of the plastics will rise to over 56 gigatonnes CO2-e, depicting 10-13 % of the global carbon budget calculated based on the 1.5 °C target (Hamilton et al., 2019). In addition, recyclability and the circularity rates are important KPI's to follow.

3.5.9 Circular packaging: Reducing demand for (over)packaging/ packaging waste, improved circular design and strategies that fully replace the need for packaging

- Authors: **VTT**
- Knowledge Repository link: **https://netzerocities.app/resource-2453**

Circular packaging: Reducing demand for (over)packaging/ packaging waste, improved circular design and strategies that fully replace the need for packaging	
There is a clear need to decrease usage of non-renewable raw materials in many applications including packaging. In packaging this means usage of **renewable raw materials** and decreasing the amount of used packaging material. Target is to produce materials from renewable raw materials that can be used as packaging materials. Packaging materials are typically multilayer structures including several materials like foils, coatings, substrates and inks. There is also need to **decrease the material amount**. This means that in multilayer structures thinner layers or less materials is used. In addition, multilayer structures are targeted to be replaced with monomaterials. All this should be done without losing the properties of the final packaging. **Recyclability** of packages and packaging materials is also in target. This is affected by **package design** and the materials used in the packaging. Widely this is linked to waste management and collection systems. Important target is also that recycled packaging materials would be used in production new materials. The final target would be fully recyclable packaging, which is based on renewable raw materials.	
CO-BENEFITS	• Promote the materials cycle
KEYWORDS	• Circular economy design principles to increase the durability, reparability, upgradability or reusability of products, in particular in designing and manufacturing activities
EXTERNAL LINKS	• http://www.actinpak.eu/showcase/ • https://projects.au.dk/circul-a-bility/ • https://urn.fi/URN:NBN:fi:tuni-202103252677

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Circular packaging: Reducing demand for (over)packaging/ packaging waste, improved circular design and strategies that fully replace the need for packaging	
PRE-CONDITIONS & ENABLING CONDITIONS	***Political:*** Use of bio-based / recycled materials are promoted and use of fossil-based materials hindered. The waste management and collection systems are promoted to favour bio-based / recycled materials. ***Economic:*** The production volumes of bio-based / recycled materials are high enough to fulfil the need and the price of the materials is comparable to existing alternatives to create a real economic solution, ***Legal:*** Bio-based / recycled materials are favoured. Materials are allowed to be used in different packages. ***Social:*** Consumers prefer and demand for bio-based / recycled materials. ***Technical:*** The bio-based materials can be processed with existing systems and they possess the required properties compared to existing alternatives.
CONSTRAINTS/ BARRIERS for implementation	***Political:*** Political decisions do not promote usage of bio-based/recycled materials and waste management systems are not developed. ***Social:*** Consumers do not understand the difference between materials and they cannot recycle in a proper way. Recycling instructions should be clear enough and waste management systems easy for consumers. ***Technical:*** The availability of bio-based / recycled materials still quite low. Processability of some bio-based materials is challenging and they may be lacking some properties. The materials should be able to be processed with existing systems (or at least with minor modifications). The source of renewable raw material should not compete with food production (the source should be e.g. some side stream). ***Legal:*** Bio-based / recycled materials not allowed in all applications (e.g. legislation related to food packages). ***Economic:*** The price of the bio-based materials is still quite high which increases the cost of packaging material and thus the price of the overall product.
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	***Economic:*** If the price of the raw materials decreases, the price of the packaging material decreases which promotes the use compared to existing alternatives. ***Environmental:*** The use of non-renewal (fossil) raw materials is decreased and the use of renewable raw materials is increased. The recycling systems can handle bio-based materials and produce recycled material for production of new materials. Recycling of packaging materials is increased which decreases waste. ***Social/Technical:***

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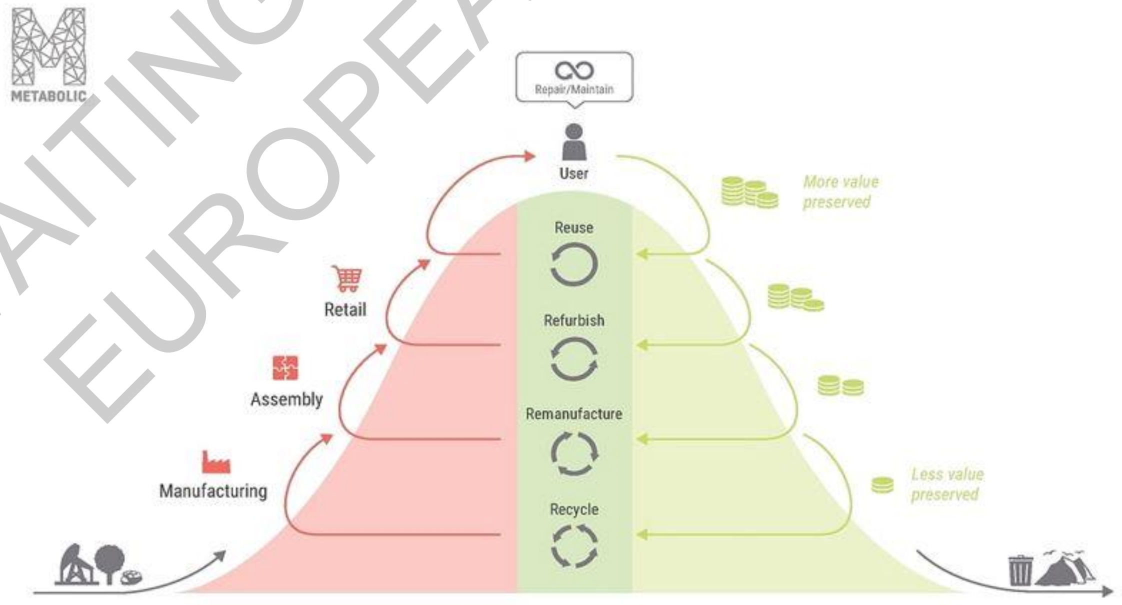
Circular packaging: Reducing demand for (over)packaging/ packaging waste, improved circular design and strategies that fully replace the need for packaging	
	The materials can be processed with existing systems and the price is comparable to existing solutions. Bio-based / recycled materials possess the required properties in order to fulfil the needs of the application.
Additional information from CASE STUDIES	• ActInPak showroom • Circul-a-bility Conference • Tiekstra, S.; Dopico-Parada, A.; Koivula, H.;Lahti, J.; Buntinx, M. Holistic Approach to a Successful Market Implementation of Active and Intelligent Food Packaging. Foods 2021, 10, 465. https://doi.org/10.3390/foods10020465

3.5.10 Construction and Buildings: Optimal management of waste at the end of building life cycle

- Authors: **METABOLIC**
- Knowledge Repository link: **https://netzerocities.app/resource-2467**

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the "orange" fields of this solution, and then it has been afterwards reviewed by JRC and completed the "pink" fields, and the Knowledge Repository content has been updated with JRC's input. So, here only the "orange" fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

Construction and Buildings: Optimal management of waste at the end of building life cycle
At the end of a building's life the majority of its materials are sent to **landfill** or downcycled into products of **much lower value**. This leads to a great loss of valuable materials and also majorly contributes to **cities' environmental footprint**. To maximize recovery and valorisation potential of existing materials in buildings and minimize waste in construction, optimal waste management at the end-of-life of buildings is essential. The **right treatment and disposal** of materials at the end of life can help to significantly reduce the construction sector's environmental footprint:



Source: Metabolic Institute

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Construction and Buildings: Optimal management of waste at the end of building life cycle	
Urban mining – the process of recovering and reusing a city's materials – can offer a viable solution to improve waste management in the construction sector. While the majority of construction and demolition waste can easily be recycled, most of it is downcycled and used primarily outside the sector, leading to a loss of value. Using the recovered materials for new building projects, however, has a great advantage: By keeping the materials in the city, long supply chains can be prevented and emissions thereby reduced. Urban mining also reduces the demand for new building materials, which also significantly reduces greenhouse gas emissions. *Product life cycle stages & Modules (EN15978): C1 Disassembling/ sorting*	
CO-BENEFITS	• Reduce GHG emissions • Reduce energy needs • Boost local business (km 0)
KEYWORDS	Direct connections to **technical solutions**: • Construction and Buildings: re-using local building waste (e.g. local waste material bank) • Construction and Buildings: urban mining model to assess circular construction opportunities and optimize resource use and exchange • Construction and Buildings: residual Value Calculator for construction parts/material, consumers products etc • Construction and Buildings: online register with building and infrastructure material/parts/products for reuse/circular use • Construction and Buildings: circular Life Cycle Cost (C-LCC) for deep renovation Direct connection to **Instruments**: • Analysis of City/(Building) circularity • Circular economy design principles to increase the durability, reparability, upgradability or reusability of products, in particular in designing and manufacturing activities • Urban metabolism mapping - identifying product streams and material inputs (in addition to waste) • Circular Life Cycle Assessment/Analysis for material and products (incl. scenarios and prospective versions), also waste • Building Material Passport, BIM-based • Supporting municipalities to monitor resource flows in line with impact targets and measurement processes • Capacity building and engagement with municipalities to identify and co-create circular solutions and roadmaps
EXTERNAL LINKS	• https://houseful.eu/solutions/optimal-management-of-waste-at-the-end-of-building-life-cycle/ • https://www.researchgate.net/publication/282666541_END-OF-LIFE_PHASE_OF_A_RESIDENTIAL_BUILDING_CD_WASTE_MANAGEMENT_FROM_A_LIFE_CYCLE_PERSPECTIVE • https://eplca.jrc.ec.europa.eu/uploads/waste-Guide-to-LCTLCA-for-C-D-waste-management-Final-ONLINE.pdf • https://ec.europa.eu/docsroom/documents/20509/attachments/1/translations/en/r

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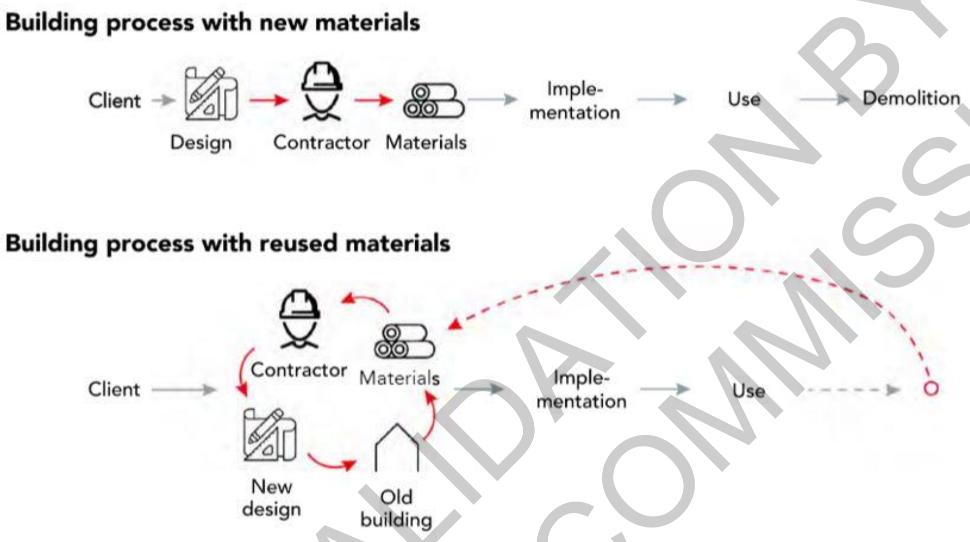
3.5.11 Construction and Buildings: re-using local building waste

- Authors: **METABOLIC**
- Knowledge Repository link: **https://netzerocities.app/resource-2477**

This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

Construction and Buildings: re-using local building waste

The re-using **local building waste is a methodology** to be applied for the reuse of materials from buildings that can be found locally to facilitate their reuse, also taking into consideration proximity aspects. The current linear economy that the building sector is operating in has major environmental impacts. Both the sourcing and production of new building materials, as well as the waste generated at the end of life phase of buildings is greatly contributing to harmful greenhouse gas emissions and increasingly risks resource scarcity. By transitioning to a **circular building industry** and re-using local building waste, the industry's environmental footprint can be significantly reduced. This transition is challenged by a loss of value of the materials due to lengthy and linear supply chains. To sustain and increase value of materials in buildings, **circular value chains need to be designed and implemented**. If successful, buildings can then function as **local material banks**, instead of being constructed to end up in landfill. The figure below shows the change in the construction process when recycled materials are used:



Source: https://www.metabolic.nl/publications/building-with-recycled-building-materials/

This solution can be combined with the solution Building Material Passport as this solution contains all the information on products, components and materials existing in a building and can be used as input for the re-using local building waste solution.

Product life cycle stages & Modules (EN15978): Full Value Chain

CO-BENEFITS

By reusing local building waste there is better use of waste management and the materials cycle will be promoted. By keeping and producing the used building materials locally, a **proximity economy** will be established which increases the **local employment rate** and jobs within the building industry.

KEYWORDS

Direct connections to **technical solutions**:

- Construction and Buildings: optimal management of waste at the end of building life cycle
- Construction and Buildings: urban mining model to assess circular construction opportunities and optimize resource use and exchange
- Construction and Buildings: residual Value Calculator for construction parts/material, consumers products etc
- Construction and Buildings: online register with building and infrastructure material/parts/products for reuse/circular use
- Construction and Buildings: circular Life Cycle Cost (C-LCC) for deep renovation

Direct connection to **Instruments**:

- Analysis of City/(Building) circularity

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Construction and Buildings: re-using local building waste	
	• Circular economy design principles to increase the durability, reparability, upgradability or reusability of products, in particular in designing and manufacturing activities • Urban metabolism mapping- identifying product streams and material inputs (in addition to waste) • Circular Life Cycle Assessment/Analysis for material and products (incl. scenarios and prospective versions), also waste • Building Material Passport, BIM-based • Supporting municipalities to monitor resource flows in line with impact targets and measurement processes • Capacity building and engagement with municipalities to identify and co-create circular solutions and roadmaps
EXAMPLES	• Circular Toolbox on Sustainability in the Built Environment, case studies from Amsterdam: https://www.metabolic.nl/news/the-circular-toolbox-delivers-resources-on-sustainability-in-the-built-environment/

Construction and Buildings: re-using local building waste	
PRE-CONDITIONS & ENABLING CONDITIONS	***Policy and regulatory/legal framework:*** The recovery of raw materials from the Urban Mine can be increased by clear and strict regulations, particularly by those which incentivize recycling over landfilling. ***Policy and regulatory/legal framework:*** Creating uniform environmental regulation across borders is important, as product and material flows between countries are complicated by using different approaches to labelling, product design and standards. If strict and uniform regulation is applied, secondary material could be directed to where the most value is conserved instead of where environmental and worker health costs are lower or are simply out of sight. E.g. Regulations and policies that require the reduction of waste and encourage the use of sustainable materials in building projects, such as LEED (Leadership in Energy and Environmental Design) certification. ***Technical aspects/infrastructure:*** Public authorities are responsible for providing adequate infrastructure for recycling, such as dedicated locations where hubs with reused materials can be installed. The industry has an important role to play both as designer and provider of products as well as collector and recycler. Product manufacturers must recognize the need to consider repair and disassembly as much as possible as part of the design process. ***R&D:*** Incentives for the development of advanced recycling technologies and adequate access to these is a pre-requisite for effective recovery of the resource potentials of an Urban Mine. ***Condition materials:*** The waste materials must be in good condition and suitable for reuse in their current form, or they must be able to be processed into a usable form through methods such as crushing, shredding, or grinding. ***Viable market:*** There must be a demand for the waste materials and a viable market for their reuse. This typically involves finding businesses or organizations that can use the materials in their operations or finding ways to repurpose the waste into new products that can be sold or used.

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Construction and Buildings: re-using local building waste	
CONSTRAINTS/ BARRIERS for implementation	***Costs:*** Many recycling processes have considerably lower carbon footprints compared to using virgin materials. However, in the case of some metals, especially from highly complex products, their recovery might result in substantial costs due to technical challenges, lower economic viability, and a higher environmental burden of the necessary processes (source). ***Lack of know-how:*** There is a general lack of know-how on effective recycling strategies of building waste. This makes it harder to motivate people to start recycling/reusing building waste as well as to make a strong case to gather funding. ***Health issues:*** The release of chemicals and toxic gases that arise in the urban mining processes threatens workers' health (source)
INSTRUMENTS/ Processes for implementation	• Training • Regulations for durability, reparability and recycling in public procurement • Material passports/ Urban metabolism mapping: https://netzerocities.app/resource-1893 • Circular economy design principles to increase the durability, reparability, upgradability or reusability of products: https://netzerocities.app/resource-1883 • Taxation: reuse/repair tax relief (source) • Green Public Procurement
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	***Reusing toxic materials:*** The main drawback would be reusing unhealthy/toxic materials (which are normally phased out after demolishing a building). ***Changing of the job market:*** Disappearance of existing workplaces, leaving people without a job if they don't retrain themselves. ***Not long-lasting:*** Another potential adverse impact is that the materials may not be as durable or long-lasting as new materials, which could result in the need for repairs or replacements sooner than expected. This could potentially increase the overall cost of the building project, as well as create additional waste if the reused materials need to be replaced.
IMPACTS (Indicators & DNSH)	Percentage of building material recycled; Financial incentives for advanced recycling technologies
	DNSH: Pollution prevention and control: One potential environmental adverse effect of reusing building waste is that it could lead to the release of hazardous substances into the environment. For example, if building materials that contain asbestos or lead paint are not properly disposed of and are instead incorporated into a building project, these materials could potentially release harmful particles into the air or water.
Additional information from CASE STUDIES	• Urban Mining Rotterdam: For every kilo of E-Waste (that is, anything with a plug and/or battery) and plastics that residents hand in to Urban Mining, participants receive a share in the form of a credit • Urban Mine: Recycling concrete using renewable energy. • Unbuilders: We are Canada's foremost deconstruction & salvage company. We dismantle buildings and salvage almost everything, including irreplaceable Old Growth lumber, windows, doors, cabinets, fixtures and appliances. • Dura Vermeer Urban Miner: Dura Vermeer Urban Miner is located in the Rotterdam region. It is a circular construction hub where, in addition to

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Construction and Buildings: re-using local building waste	
	sustainable construction logistics, they also temporarily store, process and reuse used building materials and building components.

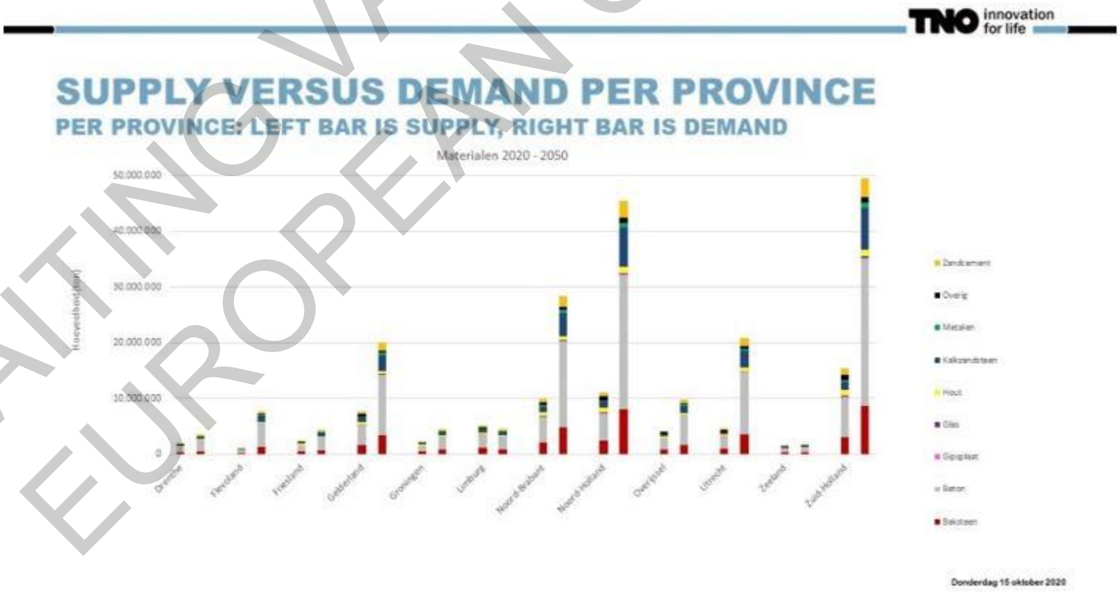
3.5.12 Construction and Buildings: urban mining model to assess circular construction opportunities and optimise resource use and exchange

- Authors: **TNO**
- Knowledge Repository link: https://netzerocities.app/resource-2487

Construction and Buildings: Urban mining model to assess circular construction opportunities and optimize resource use and exchange

Urban mining is **the process of recovering and reusing materials of existing buildings.** An **Urban Mining Model** is about preserving stock of materials present in existing buildings. It is an applied contribution towards stepping-up of circularity in the housing construction sector with a focus on optimal **re-use of secondary building materials** and, at the same time, **reduction of CO_2** relates to the use of new building materials. For city governments in particular, this model shows different possibilities for re-use based on aspects such as quality, residual value, environmental impact and logistical implications.

BOB (Bouwmaterialen in Beeld/ Building materials in Sight) is a **prediction urban mining model on the supply and demand of construction materials until 2020-2050** (see figure below). It has been applied for Assen Municipality, for which the model compared three scenarios to build in a circular manner and this resulted in a useful overview of the pros and cons per scenario and indicator. Moreover, a quick scan in Amsterdam metropolitan region, regarding the effects of circular building on logistic flows and the use of space, showed that up to a quarter of this large number of new homes can be built in a circular fashion with used materials.



Source: TNO, 2020

Product life cycle stages & Modules (EN15978): Full value chain

CO-BENEFITS	This solution could **reduce GHG emissions**, **boost local business**, contribute to **raised awareness/behavioural change**, **increased skill development** and

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Construction and Buildings: Urban mining model to assess circular construction opportunities and optimize resource use and exchange	
	better waste management. It could also **promote the materials cycle** and **reduce ecological footprint**.
KEYWORDS	Direct connections to **technical solutions**: • Construction and Buildings: optimal management of waste at the end of building life cycle • Construction and Buildings: re-using local building waste (e.g. local waste material bank) • Construction and Buildings: residual Value Calculator for construction parts/material, consumers products etc • Construction and Buildings: online register with building and infrastructure material/parts/products for reuse/circular use • Construction and Buildings: circular Life Cycle Cost (C-LCC) for deep renovation Direct connection to **Instruments**: • Analysis of City/(Building) circularity • Circular economy design principles to increase the durability, reparability, upgradability or reusability of products, in particular in designing and manufacturing activities • Urban metabolism mapping- identifying product streams and material inputs (in addition to waste) • Circular Life Cycle Assessment/Analysis for material and products (incl. scenarios and prospective versions), also waste • Building Material Passport, BIM-based • Supporting municipalities to monitor resource flows in line with impact targets and measurement processes • Capacity building and engagement with municipalities to identify and co-create circular solutions and roadmaps
EXTERNAL LINKS	• Information on 'Urban mining and circular construction – what, why and how it works': https://www.metabolic.nl/news/urban-mining-and-circular-construction/ • Prospecting the Urban Mines of Amsterdam: https://www.metabolic.nl/projects/prospecting-the-urban-mines-of-amsterdam-puma/
EXAMPLES	• A short description of the results of using the model for **Assen municipality and the metropolitan region of Amsterdam:** https://www.tno.nl/en/focus-areas/circular-economy-environment/roadmaps/circular-economy/circular-building/online-database-of-circular-building-materials/

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Construction and Buildings: Urban mining model to assess circular construction opportunities and optimize resource use and exchange	
PRE-CONDITIONS & ENABLING CONDITIONS	***Political:*** A strategy and policy where circularity (R-ladder) is being awarded above linear models ***Economic:*** Circular procurement with benefits for use of secondary materials, products and elements ***Social:*** Repair- and refurbish shops generate jobs ***Legal:*** Labels and/or certificates for dominant materials, products and elements

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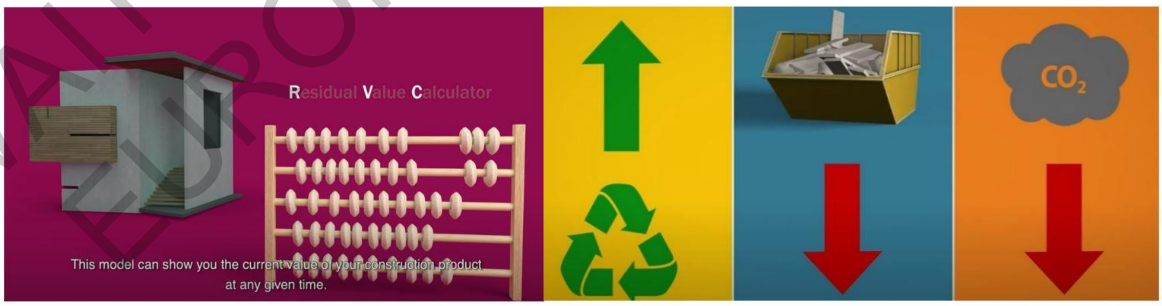
Construction and Buildings: Urban mining model to assess circular construction opportunities and optimize resource use and exchange	
CONSTRAINTS/ BARRIERS for implementation	***Political****:* tax and VAT rules ***Economic****:* financial institutes are very traditional and extreme risk avoiding ***Social****:* labour market, lack of qualified personnel ***Technical****:* harvest companies and -skills instead of traditional demolition
INSTRUMENTS/ Processes for implementation	• Analysis of City/ (Building) circularity: https://netzerocities.app/resource-1873 • Circular economy design principles to increase the durability, reparability, upgradability or reusability of products: https://netzerocities.app/resource-1883 • Urban metabolism mapping: https://netzerocities.app/resource-1893 • Circular Life Cycle Assessment/Analysis for material and products: https://netzerocities.app/resource-1903
IMPACTS (Indicators & DNSH)	Emissions, Costs
Additional information from CASE STUDIES	• A short description of the results of using the model for Assen municipality and the metropolitan region of Amsterdam. • Information on 'Urban mining and circular construction – what, why and how it works'. • Prospecting the Urban Mines of Amsterdam.

3.5.13 Construction and Buildings: Residual Value Calculator

- Authors: **TNO**
- Knowledge Repository link: **https://netzerocities.app/resource-2498**

Construction and Buildings: Residual Value Calculator	
Residual Value Calculator is a **model** that provides insights into the **residual financial value** of building products, such as the interior and exterior facades of homes and offices. The residual financial value is the financial value of building products or elements after its first life cycle. Compared to a linear business model, the financial benefits of re-use of building products and building elements are determined by calculating their residual value. Some of the indicators the tool uses, are: production costs new minus costs of maintenance, refurbishment, repair, transportation, warehousing. Combined with the environmental costs, this tool assists designers, product managers, financial managers in decision-making on potential new business models.  *Source: https://www.youtube.com/watch?v=PnFneq_PYHs&t=4s* *Product life cycle stages & Modules (EN15978): D Reuse and Recycling*	
CO-BENEFITS	This solution offers benefits for entrepreneurship and innovation, i.e. by decreasing future maintenance costs. It also promotes the materials cycle, while it raises awareness/behavioural change.
KEYWORDS	Direct connections to **technical solutions**:

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Construction and Buildings: Residual Value Calculator	
	• Construction and Buildings: optimal management of waste at the end of building life cycle • Construction and Buildings: re-using local building waste (e.g. local waste material bank) • Construction and Buildings: urban mining model to assess circular construction opportunities and optimize resource use and exchange • Construction and Buildings: online register with building and infrastructure material/parts/products for reuse/circular use • Construction and Buildings: circular Life Cycle Cost (C-LCC) for deep renovation Direct connection to **Instruments**: • Analysis of City/(Building) circularity • Circular economy design principles to increase the durability, reparability, upgradability or reusability of products, in particular in designing and manufacturing activities • Urban metabolism mapping- identifying product streams and material inputs (in addition to waste) • Circular Life Cycle Assessment/Analysis for material and products (incl. scenarios and prospective versions), also waste • Building Material Passport, BIM-based • Supporting municipalities to monitor resource flows in line with impact targets and measurement processes • Capacity building and engagement with municipalities to identify and co-create circular solutions and roadmaps
EXTERNAL LINKS	• https://www.tno.nl/en/focus-areas/circular-economy-environment/roadmaps/circular-economy/circular-building/residual-value-calculation/ • Video explaining the tool: https://www.youtube.com/watch?v=PnFneq_PYHs&t=4s

Construction and Buildings: Residual Value Calculator	
PRE-CONDITIONS & ENABLING CONDITIONS	***Political:*** A circular strategy for both new build and renovation schemes ***Economic:*** Accountancy rules that allow residual value (€) ***Social:*** Re-furbish and re-use of products and elements will provide opportunities in the local labour market ***Technical:*** Detachability of products and elements/units ***Legal:*** Strict tender rules on circularity and re-usability
CONSTRAINTS/ BARRIERS for implementation	***Political:*** tax and VAT rules ***Economic:*** financial institutes are very traditional and extreme risk avoiding Social: none ***Technical:*** a broadly accepted calculation method ***Legal:*** tax- and accountancy rules
INSTRUMENTS/ Processes for implementation	• Analysis of City/ (Building) circularity; https://netzerocities.app/resource-1873

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Construction and Buildings: Residual Value Calculator	
	• Circular economy design principles to increase the durability, reparability, upgradability or reusability of products, https://netzerocities.app/resource-1883 • Urban metabolism mapping; https://netzerocities.app/resource-1893 • Circular Life Cycle Assessment/Analysis for material and products; https://netzerocities.app/resource-1903
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	Products, elements and/or buildings with a long-life expectancy are harder to calculate residual value because of uncertainties in the far future. Steering instrument for new (circular) business model(s).
IMPACTS (Indicators & DNSH)	Costs
	Circular economy

3.5.14 Construction and Building: Online register with building and infrastructure material/parts/products for reuse/circular use

- Authors: **CKIC**
- Knowledge Repository link: **https://netzerocities.app/resource-2508**

Construction and Building: Online register with building and infrastructure material/parts/products for reuse/circular use
Online Material and/or Building Registries are a new approach to the concept of '**Buildings as Material Banks**'. Online registries can and should include both **statistical and measured specification** and **performance data** gathered from manufacturers, certifiers and verifiers, as well as sensors, inspections and measurements. This data, usually collected in Material and/or Buildings Passports, can be both an input to and an output of BIM models, LCA analysis and other types of certifications, such as Energy Performance Diagnosis (EPD), financial incentives frameworks (including smart insurance), multi-criteria evaluation models, policy development (including open data web platforms), and deconstruction / reuse processes. A key barrier to the viability of secondary construction material markets is **logistics**. By creating digital and physical platforms to coordinate efforts, cities can accelerate private actors' contributions to a circular construction sector. A principal necessity is accessing information on waste with potential to be a resource or input to other processes. The challenge of managing and evaluating the amounts of data required is best met with digital tools. Sophisticated digital tools such as BIM-supported Material and Building Passports collected in online open-source registries are central to circularity-enabling decision-making from the planning phase, through the building use phase, including retrofit cycles, and up to the disassembly and end of (first) life.

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Construction and Building: Online register with building and infrastructure material/parts/products for reuse/circular use	
Source: https://globalabc.org/news/new-report-building-passport-practical-guidelines *Product life cycle stages & Modules (EN15978): D Reuse and Recycling*	
CO-BENEFITS	• Possibly decrease future maintenance costs through early detection. • Improved access to information • Better waste management • Promote the materials cycle
KEYWORDS	Direct connections to **technical solutions**: • Construction and Buildings: optimal management of waste at the end of building life cycle • Construction and Buildings: re-using local building waste (e.g. local waste material bank) • Construction and Buildings: urban mining model to assess circular construction opportunities and optimize resource use and exchange • Construction and Buildings: residual Value Calculator for construction parts/material, consumers products etc • Construction and Buildings: circular Life Cycle Cost (C-LCC) for deep renovation Direct connection to **Instruments**: • Analysis of City/(Building) circularity • Circular economy design principles to increase the durability, reparability, upgradability or reusability of products, in particular in designing and manufacturing activities • Urban metabolism mapping- identifying product streams and material inputs (in addition to waste) • Circular Life Cycle Assessment/Analysis for material and products (incl. scenarios and prospective versions), also waste • Building Material Passport, BIM-based • Supporting municipalities to monitor resource flows in line with impact targets and measurement processes • Capacity building and engagement with municipalities to identify and co-create circular solutions and roadmaps
EXTERNAL LINKS	• https://globalabc.org/news/new-report-building-passport-practical-guidelines • https://woningpas.vlaanderen.be/ • https://madaster.com/

Construction and Building: Online register with building and infrastructure material/parts/products for reuse/circular use	
PRE-CONDITIONS & ENABLING CONDITIONS	***Political:*** A strategy and policy where circularity (R-ladder) strategies are being awarded above linear models, for example, building components being reused over going to landfill or waste for energy incineration. ***Economic:*** Circular procurement with benefits for use of secondary materials, products and elements ***Social:*** Repair- and refurbish shops generate jobs. Acceptance for using secondary and waste materials by users is needed. ***Technical:*** Labels and/or certificates for dominant materials, products and elements.

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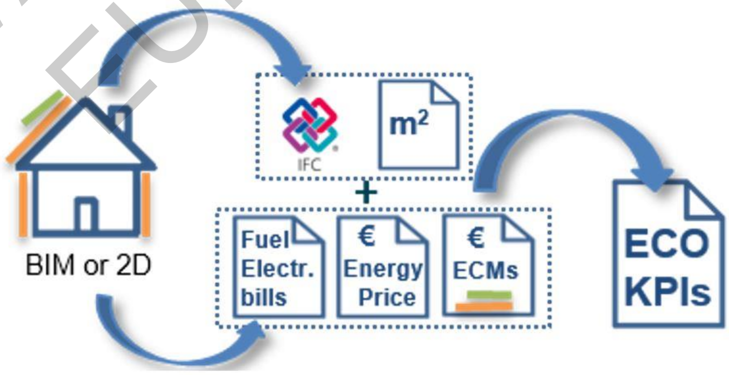
Construction and Building: Online register with building and infrastructure material/parts/products for reuse/circular use	
	Legal: Legal use of the products before they become waste needs to be established.
CONSTRAINTS/ BARRIERS for implementation	***Political:*** tax and VAT rules ***Economic:*** financial institutes are very traditional and extreme risk avoiding. Virgin materials are much cheaper than secondary or waste materials. ***Social:*** labour market, lack of qualified personnel. Perception of risk for using secondary materials. ***Technical:*** harvest companies and -skills instead of traditional demolition ***Legal:*** legal definition of waste
INSTRUMENTS/ Processes for implementation	Municipal and central government procurement practices. Support for digital infrastructure, including who owns and can access the database.
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	Reliability of the data, and assurance or guarantee for the quality of the secondary product/material/parts.
Additional information from CASE STUDIES	See examples from Bamb BAMB - Buildings As Material Banks (BAMB2020) - BAMB Urban Mining Urban Mining Scan - New Horizon

3.5.15 Construction and Buildings: Circular Life Cycle Cost (C-LCC) for deep renovation

- Authors: **CARTIF**
- Knowledge Repository link: **https://netzerocities.app/resource-2518**

Construction and Buildings: Circular Life Cycle Cost (C-LCC) for deep renovation
The **Circular Life Cycle Cost** (C-LCC) is a **methodology** to automatize the calculation of **economic indicators** applied to deep renovation projects of existing buildings, collecting operational and maintenance data, and investment costs. The objective of the C-LCC solution is to obtain a set of economic indicators with the purpose of improve the design of deep renovation projects and promote the cost-effective renovations. This allows owners (and project designers, etc.) to know, among other parameters, the return of the investment of a renovation project in the design phase, the operational energy costs, and the future maintenance costs of the solutions implemented in the renovation phase, improving the decision-making process.  *Source: © Sonia Álvarez Díaz, CARTIF*

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This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

Construction and Buildings: Circular Life Cycle Cost (C-LCC) for deep renovation	
The economic indicators included in this solution are: Operational Energy Costs, Investment, Life Cycle Cost, Return of Investment (ROI), and Payback Period. Product life cycle stages & Modules (EN15978): Full Value Chain	
CO-BENEFITS	• Economic: Entrepreneurship and innovation --> Decrease future maintenance costs • Social: Enhancing citizen participation, connectivity, and community • Resource Efficiency: Waste Efficiency --> Promote the materials cycle • The calculation of the Life Cycle Cost in the design of a deep renovation building project will encourage owner's knowledge about the economic information of a deep renovation projects and the operational energy cost of the building/dwelling, as well as its future maintenance cost.
KEYWORDS	Direct connections to **technical solutions**: • Construction and Buildings: optimal management of waste at the end of building life cycle • Construction and Buildings: re-using local building waste (e.g. local waste material bank) • Construction and Buildings: urban mining model to assess circular construction opportunities and optimize resource use and exchange • Construction and Buildings: residual Value Calculator for construction parts/material, consumers products etc • Construction and Buildings: online register with building and infrastructure material/parts/products for reuse/circular use Direct connection to **Instruments**: • Analysis of City/(Building) circularity • Circular economy design principles to increase the durability, reparability, upgradability or reusability of products, in particular in designing and manufacturing activities • Urban metabolism mapping- identifying product streams and material inputs (in addition to waste) • Circular Life Cycle Assessment/Analysis for material and products (incl. scenarios and prospective versions), also waste • Building Material Passport, BIM-based • Supporting municipalities to monitor resource flows in line with impact targets and measurement processes • Capacity building and engagement with municipalities to identify and co-create circular solutions and roadmaps
EXTERNAL LINKS	The ECOtool, developed by CARTIF, automatically calculates a set of indicators: Operational Energy Costs, Investment, Life cycle cost, Return of Investment, Payback Period, Operational Primary Energy Demand and Global Warming Potential.

Construction and Buildings: Circular Life Cycle Cost (C-LCC) for deep renovation	
PRE-CONDITIONS & ENABLING CONDITIONS	***Technical aspects/infrastructure:*** The technical aspects affecting the C-LCC methodology focus on the input data requirements. Information on the investment of the proposed solution, as well as the information on the materials to be used, e.g. replacement cost, the estimated service life of each of the elements, is mandatory for the calculation of the LCC. Another requirement is to know the consumption of fuel and electricity, using measured data or the bills of the building, and the energy price and the energy price increase, and also the maintenance cost. If a BIM model of the building is available, it is necessary that it has the information on the square meters of the building /dwelling, if not, this information needs to be known to the end-user/owner/technician.

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<table>
<tr><th colspan="2">Construction and Buildings: Circular Life Cycle Cost (C-LCC) for deep renovation</th></tr>
<tr><td></td><td>Policy and regulatory/legal framework:
The ISO 15686-5:2017 provides a set of specific requirements and guidelines for calculating the C-LCC for news and for deep renovation projects. Different action plans could also be taken into consideration, such as the Circular Economy Action Plan (CEAP) launched by the European Commission, as well as the Sustainable Products Initiative (SPI.) The revised Construction Product Regulation (CPR) has set new rules to enhance the sustainability of construction products, having as one of its objectives the improvement of digital product information for citizens, businesses and other stakeholders.

Economic and social context:
The C-LCC methodology can help citizens to improve the decision-making in new and deep renovation projects of a building, allowing the owner to reduce future costs based on the selection of materials to be used in the building.</td></tr>
<tr><td>CONSTRAINTS/ BARRIERS for implementation</td><td>Technical aspects/infrastructure:
Some previous studies have identified that among the main barriers to C-LCC implementation are the lack of reliable data, lack of knowledge of the client and lack of experience of the professional team in charge[12]. The implementation of the C-LCC requires expert knowledge to define the necessary input data for the calculations, if it is based on BIM, e.g. based on the IFC standard, a correct model needs to be defined to automatically obtain the information on the square meters of the building or dwelling to be analysed. The development of automatic tools that only require data that is easily accessible to the end-user can facilitate the calculation of the C-LCC, as does the simplified version of the ECOtool for some calculations of economic indicator that will be used later to calculate the LCC [13].

Policy and regulatory/legal framework:
The regulations already mentioned in the pre-conditions, such as the ISO 15686-5:2017.

Economic and social context:
The methodology defined by the C-LCC will increase the digital skills in the construction sector, and will also allow it to be linked to other emerging initiatives that are also being promoted by the European Union, such as the use of Digital Building Logbook (DBL).</td></tr>
<tr><td>INSTRUMENTS/ Processes for implementation</td><td>Regulatory instruments:
Use the Building Renovation Passport (BRP) as a starting point for recommendations for possible renovations to be carried out on a building in the next 15-20 years.
Use Building Material Passport (BIM-based) to know all the information of the elements and materials included in a building, the As-Built model, which will be used to improve the circularity of the materials for a renovation project, and adapt the proposed solutions according to the real state of the building.</td></tr>
<tr><td>DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation</td><td>Economic and social context:
Implementing the use of C-LCC calculation will visualise future costs that will need to be taken into consideration, rather focusing only on current investment costs.</td></tr>
</table>

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[12] Z. A. Mohd Zaki, A. Mohamad Kamil, M. T. Saidin, N. A. Adillah Ismail, and N. A. Isnaini Janipha, "Barriers of Life Cycle Costing on Construction Consultant Practice in Malaysia," IOP Conf. Ser. Earth Environ. Sci., vol. 385, no. 1, Nov. 2019, doi: 10.1088/1755-1315/385/1/012061.
[13] S. Álvarez-Díaz, "Use Case: Assessing operational energy costs and energy performance of buildings using measured data | Use Case Management," Valladolid, 2023. Accessed: Mar. 13, 2023. [Online]. Available: https://ucm.buildingsmart.org/use-case-details/2935/en.

This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

Construction and Buildings: Circular Life Cycle Cost (C-LCC) for deep renovation	
IMPACTS (Indicators & DNSH)	• Help technicians and end-users (owners, etc.) to make better decisions based on the results obtained for the LCC of the solutions to be implemented in renovation projects or in new constructions. • The application of the LCC can help to reduce the cost of the measures or solutions to be applied, by knowing in advance the future cost of possible changes and renovations of elements. • Promote the circularity of materials included in the life-cycle of a building, which will result in a reduction of GHG emissions.
	DNSH: Climate change mitigation, Circular economy
Additional information from CASE STUDIES	The cost of implementation will be influenced by two main factors: (1) the availability of reliable data, and (2) the use of tools for the automatic calculation of the LCC, such as the ECOtool, developed for this purpose.

3.5.16 Reduction of raw materials, waste and integration of secondary materials

- Authors: **Tecnalia**
- Knowledge Repository link: **https://netzerocities.app/resource-2532**

Reduction of raw materials, waste and integration of secondary materials
The necessity for urban transformation towards a circular economy (CE) system is becoming more evident as urban population and waste generation are increasing. To face this challenge of decoupling the economy from natural resources extraction, the cities need to adhere to several programs and strategies established by national, regional and municipal levels such as CE Action Plans. Local policy makers can make public local commitment to tax and regulatory reforms, or promote legislation adaptation, prescribing green public procurement etc. Regarding the reduction of raw materials and waste, currently in many countries, **economic incentive regulations** along with providing easily **accessible recycling services** have prompted improvements in recycling rates. Finding synergies and new valorisation routes among waste-streams, can promote not only sustainable benefits but also feasible circular business models and new markets for materials that were landfilled or incinerated so far. Regarding the integration of **Secondary raw materials** (SRM), SRM are recycled materials that can be used in manufacturing processes instead of virgin raw materials. The use of SRMs faces a number of barriers, including the absence of EU-wide quality standards for certain materials, difficulties linked to the SRM trading across the EU or the acceptance from the consumers. New technologies enabling the tracking from waste to reusable SRM can make the value chain more transparent ensuring trust between all the stakeholders in the recycling process.

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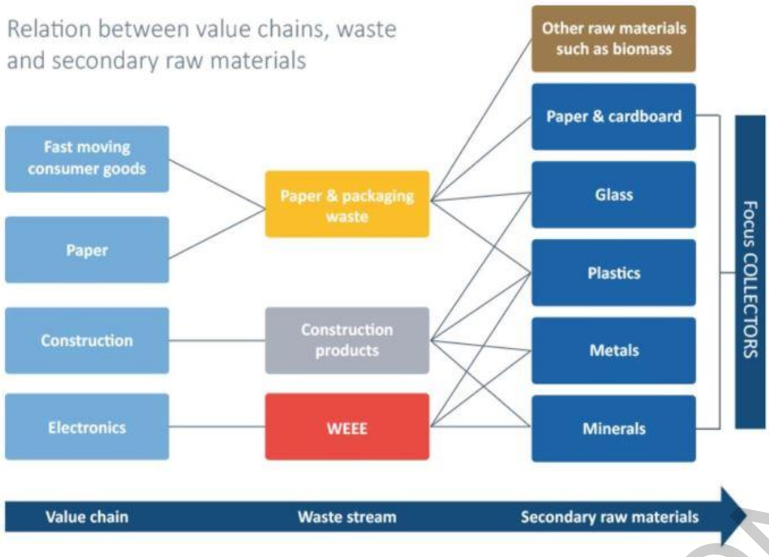
Reduction of raw materials, waste and integration of secondary materials	
 *Source:* https://www.collectors2020.eu/ In general, the **engagement of end-users and key stakeholders** will increase the social acceptance of the decisions and will facilitate the inclusion of sustainable behaviour amongst citizens. Social innovation is a key driver, ensuring a participative and democratic policy-making process. *Product life cycle stages & Modules (EN15978): Full Value chain.*	
CO-BENEFITS	• Efficient valorisation of **local resources** in cities and regions, improves circularity and reduced GHG emissions. • Creation of **business opportunities** in the circular economy at urban and/or regional scale. • **Social awareness** and environmental consciousness from **education** and politics will be the way to speed up the change that the European Green Deal demands • Many **jobs and opportunities** can be created directly and indirectly.
KEYWORDS	Direct connection to Instruments: • Supporting municipalities to monitor resource flows in line with impact targets and measurement processes • Capacity building and engagement with municipalities to identify and co-create circular solutions and roadmaps • Capacity building for city officials to understand urban metabolisms and circular solution opportunities • Building material passport (BIM-based)
EXTERNAL LINKS	• Identify and highlight existing good practices of waste collection and sorting: https://www.collectors2020.eu/ • Information on current and past circular city initiatives on policy (among others) can be found on The Circular City Centre (C3) web page: https://eiah.eib.org/_tools/resources/documents/the-c3-circular-cities-resources-inventory.pdf) • Circular Cities & Regions Initiative (CCRI) will facilitate collaboration and knowledge on circular solutions at local level. Among others circular solutions bases on resource recovery will be the challenge: https://circular-cities-and-regions.eu/

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Reduction of raw materials, waste and integration of secondary materials	
PRE-CONDITIONS & ENABLING CONDITIONS	***Political:*** Local and regional governments should elaborate a clear circular economy agenda. Representatives from all relevant policy departments should be involved, but a clear lead should be appointed for the process. Stakeholders from all parts of society and economy should also be consulted and invited to contribute. This has the double purpose of raising awareness of the initiative and of getting the buy-in from the relevant actors. Mechanisms to encourage interaction between stakeholders along the triple- or quadruple-helix should be identified and promoted. Such stakeholder interactions exercises were identified in the *UrbanWINS* project and could be, e.g., world cafes, brainstorming exercises, idea rating sheets, etc. ***Economic:*** Increasing prices of (primary) raw materials, as well as uncertain future commodity supply and price volatility. Greening of the tax system in the following ways (which are not mutually exclusive): by allowing tax benefits for green activities, by charging non-green, unsustainable and harmful activities, by shifting from taxing labour to taxing the use of (primary) raw materials, to incentivise the use of re-used/re-cycled materials. Measures to create market formation may be another very useful means to support the transition to circular approaches. The pioneering role of public procurement can be one out of several means to do so. ***Social:*** Circular economy aspects should be included in a systematic manner in the curricula of university degrees and other (vocational) qualifications. This should be the case not only in technical domains, but also in business and economics, public administration and policy-related areas. ***Technical:*** The circular design of products should be actively promoted, if not made obligatory. Practices that limit, inhibit or completely block the possibility for reuse or remanufacturing should be forbidden. Spatial proximity can enable economies of scale of low value waste and facilitate effective waste separation systems and/or infrastructure supporting circular solutions. This is particularly true for construction waste. An area where technology can really drive the circular economy is digitalisation, e.g., through Internet of Things (IoT), Big Data or (knowledge/resource) sharing platforms. Standardisation for circular products and solutions should be promoted across all sectors and value chains. ***Legal:*** As much as legislation can be a barrier, it can also act as driver for circular solutions, e.g., through bans on specific products or recycling targets.
CONSTRAINTS/ BARRIERS for implementation	***Political:*** A lack of a clear vision and will and, based on that, poor policy formulation; At local level, the lack of vision for a circular city creates an obstacle for change. In some cases, a holistic vision that unifies different smaller projects is missing (*REFLOW*) or the definition of sustainability in cities is weak and causes confusion between partners and stakeholders (Pop-Machina). Another barrier is missing or unclear collaboration across departments (on the public side) or along the value chain (on the private side). Limited knowledge exchange between stakeholders and companies, administrations and/or actors implementing circular economy approaches. In combination with the lack of relevant training among regulators and a lack of human resources, this limits to a great extent the implementation of circular economy solutions. ***Economic:*** Many financial and economic factors currently still hamper the application of circular solutions oriented to raw material use and waste reduction. These range from difficulties in accessing capital (in form of loans, venture capital but also public

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<table>
<tr><th colspan="2">Reduction of raw materials, waste and integration of secondary materials</th></tr>
<tr><td></td><td>subsidies) for relevant initiatives to the long and/or uncertain payback times of relevant projects. In addition, higher production and implementation costs of circular products, often linked to high upfront investment costs are also important economic barriers. This may also refer to the higher costs of related infrastructure. Yet another important barrier are often the missing or immature markets, both on the supply and the demand side, and in terms of distribution and logistics. Finally, taxation also often behave as limiting factor as it typically focusses on the amount of labour that is going into products, which is higher in the case of circular products.

Social:
Limited understanding and attitudes on the part of the general public towards circular economy solutions and their need.

Technical:
The fact that products (in the widest sense of the term) are not designed to be reused, remanufactured or recycled is one of the key barriers to raw material use and waste reduction.
For the field of construction, there is a lack of circular design guidance in the Member States (Cinderela project). Also, in the electronics (incl. e-mobility) sector, products are rarely designed to be circular. This concerns not only the design per se, but also the lack of transparency (i.e., documentation) on the design, which makes it challenging or impossible to disassemble products and access the various materials. Quite often, this is even done on purpose, to create barriers for other companies in the repair/reuse sector (Circ4Life).
In the case of plastics packaging, different types of polymers are often combined, which makes recycling very difficult, if not impossible (CIRC-PACK). Existing waste separation systems or infrastructures do not support circular solutions. This applies to a range of different sectors, in particular construction: when old buildings are demolished, separation of materials is rather rare. This in turn decreases the potential and performance of secondary raw materials.
Another challenge in the field of plastics packaging is a variety of different plastics materials cannot be separated by the collection and sorting systems. For this reason, plastic recycling systems are usually not able to deliver high-quality content, but only mixed-polymer plastics, for which the application areas are limited (PlastiCircle).
Lack of space when ‘parking’ waste before bringing it back into the material loop. The recycling of materials is hampered by the fact that the exact composition of collected materials are generally not known. This issue is relevant e.g., in the case of household waste (REPAiR, CityLoops, UrbanWINS) and plastics packaging (CIRC-PACK).
Lack of standardisation is one of the key barriers to reduction of raw materials, waste and, above all, integration of secondary materials. The lack of common standards, definitions and certifications poses a problem for the electronics sector, for example with respect to the labelling of recycled products (Circ4Life).
Legal:
Lack of an (adequate) regulatory framework is one of the most important barriers to the successful implementation of circular solutions. This applies to legislation both on the collection and treatment of waste, but also on the reuse of materials (e.g., through missing end-of-waste criteria). In addition to legislation per se, it is also poor implementation as well as a lack of enforcement which constitutes problems. Difficulties with respect to monitoring due to data availability issues as well as different measurement systems may in some cases be linked to that issue. Bureaucratic hurdles as well as inadequate spatial and urban planning constitute further issues.</td></tr>
</table>

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Reduction of raw materials, waste and integration of secondary materials	
	Proper data on available resources and their flows is a critical enabler. Some countries have data resources available and accessible in formats enabling an easy and correct quantification and classification of wastes from different streams, others have not. Accessible and accurate data on waste generation are crucial for the analysis and assessment of the waste streams as sources of SRM for the purpose of the business model (*Cinderela* project). Decision makers and policy setters in regions and cities are key players in implementing circular economy business models. Without their support to make the proper data available, setting up business models based on regionally/locally available potentials may be difficult this new business models.
INSTRUMENTS/ Processes for implementation	**Circular/green procurement** can be an important tool for testing/implementing legal requirements in e.g., public buildings/project development. • Supporting municipalities to monitor resource flows in line with impact targets and measurement processes https://netzerocities.app/resource-1528 • Capacity building and engagement with municipalities to identify and co-create circular solutions and roadmaps https://netzerocities.app/resource-1548 • Capacity building for city officials to understand urban metabolisms and circular solution opportunities https://netzerocities.app/resource-1568 • Capacity building and training https://netzerocities.app/resource-1578 • Educational/ Capacity building barriers identification https://netzerocities.app/resource-1588 • Integrated land use and urban planning with energy and climate https://netzerocities.app/resource-1678 • Integrated land use planning and urban space management with mobility planning https://netzerocities.app/resource-1688 • Sustainable Urban Mobility Plan (SUMP) https://netzerocities.app/resource-1708 • Decarbonisation Plans for Industry https://netzerocities.app/resource-1718 • Governance EU Climate Neutrality Framework https://netzerocities.app/resource-1728 • Building Renovation Passport (BRP) https://netzerocities.app/resource-1748 • Building Material Passport (BIM-based) https://netzerocities.app/resource-1833 • Analysis of City/ (Building) circularity https://netzerocities.app/resource-1873 • Circular economy design principles to increase the durability, reparability, upgradability or reusability of products https://netzerocities.app/resource-1883 • Urban metabolism mapping https://netzerocities.app/resource-1893 • Circular Life Cycle Assessment/Analysis for material and products https://netzerocities.app/resource-1903
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	One of the key issues is the availability of regional data concerning the waste streams that could become sources of secondary raw materials to be used in urban projects. Getting the right information on the types, location and availability of waste streams, as well as the actors behind them, seems to be quite challenging. Sometimes this is not possible because there is not accessible and accurate data on waste generation (*Cinderela* project). Pros and cons after implementation - Only close cooperation between public companies, citizens, industry, and local self-government can lead to a successful interconnected system that optimizes resources and results - economic, environmental, and social. After the implementation new opportunities for testing

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Reduction of raw materials, waste and integration of secondary materials	
	a new Second Raw Material (SRM) used to appear. It is the case of the city of Maribor (https://fibointercon.com/business-cases/circular-economy-examples/=)
IMPACTS (Indicators & DNSH)	• Municipal waste generation per capita: EU 2021 average is 530 kg • Circularity rate (share of secondary material reintroduced in the economy): EU average is 11.7% • Resource productivity (quantifies the relation between economic activity - expressed by gross domestic product (GDP) - and the consumption of material resources - measured as domestic material consumption (DMC): EU average 2021 is 135 EUR PPS/tonnes References: • EC CE monitoring framework: https://ec.europa.eu/eurostat/web/circular-economy/indicators/monitoring-framework • Bianchi et al. 2022: Regional monitoring frameworks for the circular economy: implications from a territorial perspective: https://www.tandfonline.com/doi/pdf/10.1080/09654313.2022.2057185
	A key recommendation from Circular Economy perspective is to avoid setting recycling targets, as these may translate into planning technology lock-in infrastructures, which require very high amount of waste generation flows for very long time to be economically viable. Prioritise waste reduction.
Additional information from CASE STUDIES	• **City of Maribor** (https://fibointercon.com/business-cases/circular-economy-examples/=) • **CCRI** - https://circular-cities-and-regions.ec.europa.eu/#:~:text=What%20is%20the%20Circular%20Cities,Circular%20Economy%20Action%20Plan%202020. Circular Cities and Regions Initiative • **CCD-Report** https://circularcitiesdeclaration.eu/about/ccd-report Circular Cities Declaration • **UrbanWINS** – 2016-2019 (www.urbanwins.eu) is a H2020 project that studied how cities consume resources and products, and how they eliminate the waste produced, in order to develop and test innovative plans and solutions aimed at improving waste prevention and management. The project analysed strategies for waste prevention and management in a total of 24 cities and assess how they contribute towards resilience and resource efficiency. • **Cinderela Project** - https://www.cinderela.eu/ - new circular economy business model for more sustainable urban construction • **Circ4Life** – https://www.circ4life.eu/ - A circular economy approach for lifecycles of products and services • **CIRC-PACK** – https://www.circpack.eu/ - Towards circular economy in the plastic packaging value chain • **PlastiCircle** - https://plasticircle.eu/home/ - Too valuable to waste • **REPAiR** - https://h2020repair.eu/ - Resource Management in Peri-urban Areas: Going Beyond Urban Metabolism • **CityLoops** - https://cityloops.eu/ - Closing the loop for urban material flows • EC CE monitoring framework, https://ec.europa.eu/eurostat/web/circular-economy/indicators/monitoring-framework • Bianchi et al. 2022: Regional monitoring frameworks for the circular economy: implications from a territorial perspective, https://www.tandfonline.com/doi/pdf/10.1080/09654313.2022.2057185

3.5.17 Greywater and rainwater reuse at building level

- Authors: **CARTIF**

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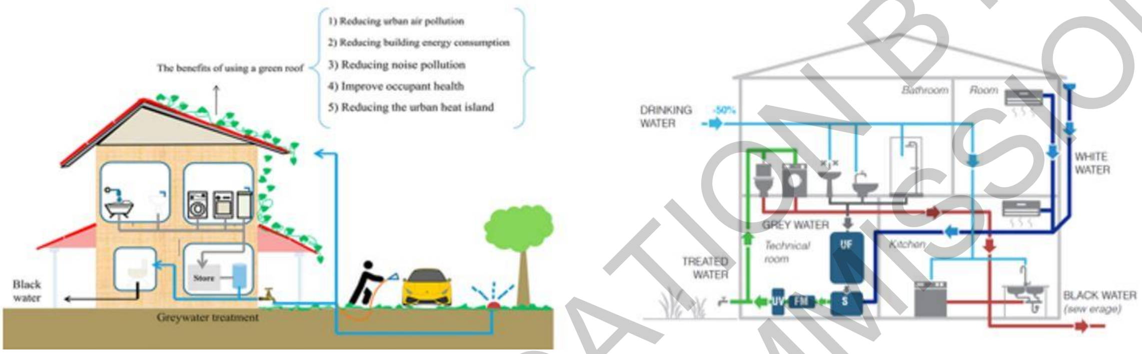
- Knowledge Repository link: **https://netzerocities.app/resource-2543**

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the “orange” fields of this solution, and then it has been afterwards reviewed by JRC and completed the “pink” fields, and the Knowledge Repository content has been updated with JRC’s input. So, here only the “orange” fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

Greywater and rainwater reuse at building level

Greywater is the wastewater generated in households or office buildings such as water from baths, sinks and washing machines, that does not contain serious contaminants. Greywater can be separated from blackwater (water from toilets or kitchens) and then treated on-site for direct reuse in toilets recharge or irrigation providing a reduction of tap-water use in the buildings.



Source:
Left: https://www.sciencedirect.com/science/article/pii/S0301479721010537
Right: https://redi.eu/greywater-recovery-system/

The decentralized process consists of several stages starting with the (i) greywater separation, (ii) storage, (iii) treatment by innovative Nature based Solutions (NBS) as multi-level green walls/ green façades or by mechanical systems as multi-layer filters and activated carbon (iv) final disinfection using commercial O3/UV systems.
Water meters at household and building level can show the amount of reused water.
When using NBS on the façade, **rainwater reuse of >95% can potentially be obtained**, together with the microclimate improvement for the cooling of the building and **preventing the heat island effect**.

Systems can be introduced in new buildings or in existing buildings with retrofitting measures.

Product life cycle stages & Modules (EN15978): C3 Waste processing + A1 Raw materials supply.

CO-BENEFITS	• Better water management • Reduce GHG emissions • Reduce energy needs • Increase technological readiness
KEYWORDS	• Direct connection with • Efficient treatment and reuse of un-segregated water at building level • Green walls and green façades.
EXTERNAL LINKS	• HOUSEFUL Project: https://houseful.eu/solutions/efficient-treatment-and-reuse-of-rainwater-and-greywater/ • https://www.sciencedirect.com/science/article/pii/S0301479721010537 • https://redi.eu/greywater-recovery-system/

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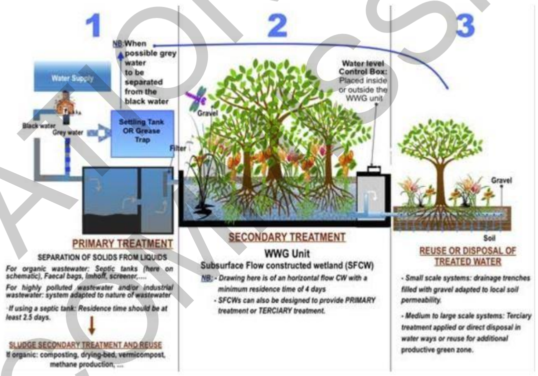
3.5.18 Efficient treatment and reuse of un-segregated water at building level

- Authors: **CARTIF**
- Knowledge Repository link: **https://netzerocities.app/resource-2554**

Efficient treatment and reuse of un-segregated water at building level

Solid and liquid/solid free waste fractions generated in households can be separated for further valorisation. Separation technologies include commercial mechanical techniques as screw press or decanting centrifuges.

Once separated, the **solid fraction can be converted into biogas** in an anaerobic digestion unit to be used within the building. On the other hand, the liquid fraction (solid free) can be treated with indoor and/or outdoor Nature Based Solutions (NBS) such as multi-level green walls/ green facades or constructed wetlands with a minimum energy cost allowing >95% water reuse. The effluent water can further be disinfected (by using O3/UV) and used for producing **valuable fertilizer** as well as **toilet flushing**.



Sources:
Left: http://en.puxintech.com/domesticbiogasplant
Right: https://sites.google.com/a/alamsantidesign.com/alamsantidesign---copy/permaculture-developments/wastewater-management

Systems can be introduced in new buildings or in existing buildings with retrofitting measures.

Product life cycle stages & Modules (EN15978): D Reuse and Recycling.

CO-BENEFITS	• Better water management • Reduce GHG emissions • Reduce energy needs • Promote the materials cycle • Better waste management
KEYWORDS	Direct connection to technical solutions: • Greywater and rainwater reuse at building level • Waste to energy (co-digestion) at building level • Multi-level green walls/ green façades • Constructed wetlands
EXTERNAL LINKS	• HOUSEFUL Project: https://houseful.eu/solutions/efficient-treatment-and-reuse-of-un-segregated-water/ • http://en.puxintech.com/domesticbiogasplant • https://sites.google.com/a/alamsantidesign.com/alamsantidesign---copy/permaculture-developments/wastewater-management

AWAITING VALIDATION BY THE EUROPEAN COMMISSION

This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

<table>
<tr><th colspan="2">Efficient treatment and reuse of un-segregated water at building level</th></tr>
<tr><td>PRE-CONDITIONS & ENABLING CONDITIONS</td><td>Technical aspects / infrastructure:
The efficient treatment of un-segregated water in buildings is implemented through a complex serial stages and with several technical requirements:
Separation of liquid/solid fraction of wastewater: equipment for the separation of wastewater (for example, a chamber tank). Dimensioning and depth according to legal requirements based on the inflow volume of person equivalent (PE).
Treatment of liquid fraction with NBS (constructed wetlands and multi-level green walls/ green façades): NBS to be built on the appropriate facing wall orientation (southern). A compost heater can be implemented to optimize the biological activity, together with temperature control, humidification through automatically controlled systems or plant-based air-filter for air purification.
Post-treatment using commercial O_3/UV hygienisation.
On the other hand, the space requirement for the water pipes and green walls/façades or the land availability for the wetlands needs to be considered. Safety measures to prevent leakages in all the installations, especially the ones which carry wastewater in any form (chamber tank, pressure pipes, sewer pipes, etc.)
Project governance and implementation modalities:
A common governance challenge is the lack of a clear construction and maintenance responsibility, as a multi-stakeholder participation and agreement is typically needed. This also has implications for the financing of the project (real estate, capital and maintenance expenditures). The multi-disciplinary nature of these schemes (ecology, hydrology, engineering), as well as the limited availability of monitoring data from case studies, make design and implementation more challenging - thus considered riskier compared to traditional engineering approaches.

Social context:
For renovation projects, it is necessary to find consensus in multi-owner buildings.</td></tr>
<tr><td>CONSTRAINTS/ BARRIERS for implementation</td><td>Technical:
Maintenance over long term, continuous, periodic sampling and analytics (physico-chemical and microbial parameters).

Policy and regulatory/legal framework:
Compliance with current regulations regarding wastewater discharge, water reuse, management of wastes or sanitary requirements:
The EU Water Reuse Regulation. The requirement of periodic sampling is a barrier (logistically, financially, etc.) for using on-site or decentralised water treatment systems.
EU wastewater discharge regulation. Obligation for sewage disposal and connection to the municipal sewage treatment plant.
Taxes and charges for building permits can be a barrier for further implementation.

Social:
Need of end-user engagement (tenants and residents) in renovation projects and their concern about noise or odour generation or the potential increases of the renovation costs, and thus, rents.</td></tr>
<tr><td>INSTRUMENTS/ Processes for implementation</td><td>One-stop-shop for building renovation https://netzerocities.app/resource-1913
Instruments for incorporating innovative solutions in public procurement: EU Briefing on Innovation Partnerships:
https://ec.europa.eu/docsroom/documents/47178</td></tr>
<tr><td>DRAWBACKS/ ADVERSE IMPACTS of the</td><td>Wetlands are typically associated with the emission of GHG, particularly methane. A comparative life-cycle assessment should be carried out with alternative traditional engineering measures to assess contributions to net-zero [1].</td></tr>
</table>

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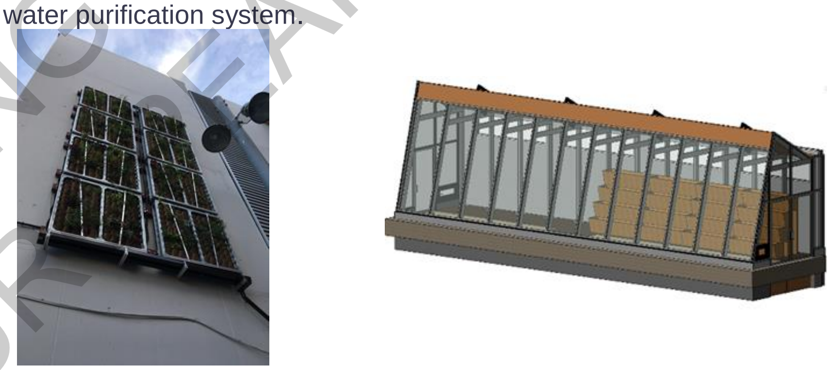
Efficient treatment and reuse of un-segregated water at building level	
solutions after implementation	
IMPACTS (Indicators & DNSH)	**Air quality:** The plants are able to absorb polluting substances. Green space management: NBS increase the green areas and create new little ecosystems. **Potential of economic opportunities and green jobs:** This NBS creates new value chains including implementation and maintenance jobs. **Indicative KPIs:** Water reuse: 95%. For other KPIS, see: • Green walls and green façades: https://netzerocities.app/resource-174 • Constructed wetlands: https://netzerocities.app/resource-1378
	Climate change mitigation: Multi-level green walls/ green façades increase thermal insulation in the building and therefore reduce the use of energy in air conditioning and heating. Constructed wetlands: GHG emissions, particularly methane (eq tons CO_2); ***Circular economy:*** Reclaimed water reuse can be a major benefit for garden or agricultural irrigation, toilet flushing, street cleaning, etc.
Additional information from CASE STUDIES	***HOUSEFUL Project demo-sites:*** Residential building El mestres (Sabadell, Spain): The building consists of eight residential floors with two flats per floor. It is adjacent to an educational centre and was initially intended as a teachers' residence. The building has become increasingly disused over recent years and all 16 flats need deep refurbishment. The refurbishment project foresees the implementation of the **multilayer façades**. Residential building Ronda Arraona, 30 (Sant Quirze del Vallès Spain): It was constructed in 2002 and it consists of 30 residential units of rental social houses distributed in 3 blocks. The refurbishment project foresees the implementation of green façades. Cambium Community Center Kasernstrasse 2, (Fehring, Austria). A former military barrack built in 1960. The refurbishment project foresees the implementation of the water purification system.  *Houseful project. Green façades (left) and water purification system (right).* [1] D. de la Varga, I. Ruiz, J.A. Álvarez, M. Soto, Methane and carbon dioxide emissions from constructed wetlands receiving anaerobically pretreated sewage, Science of The Total Environment, Volume 538, 2015, Pages 824-833, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2015.08.090.

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This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

3.5.19 Industrial symbiosis assessment and solution pathways for facilitating cross-sectoral energy and material exchange

- Authors: **Tecnalia**
- Knowledge Repository link: https://netzerocities.app/resource-2564

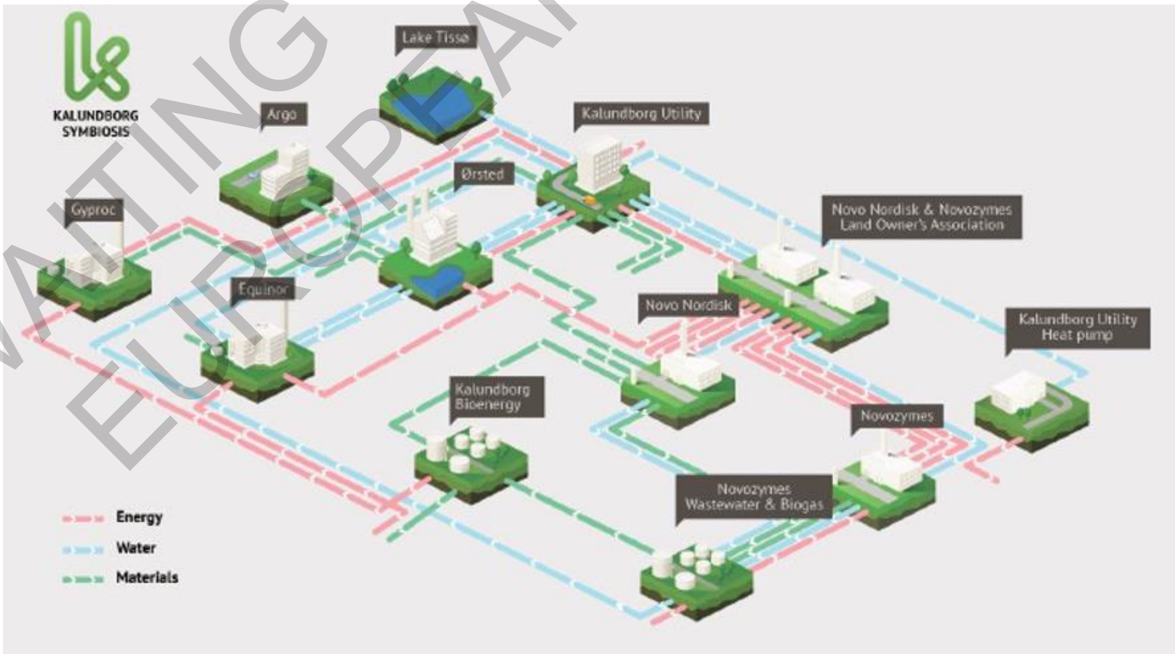
As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the “orange” fields of this solution, and then it has been afterwards reviewed by JRC and completed the “pink” fields, and the Knowledge Repository content has been updated with JRC’s input. So, here only the “orange” fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

Industrial symbiosis assessment and solution pathways for facilitating cross-sectoral energy and material exchange

Industrial symbiosis (IS) is the use by one company or sector of underutilised resources broadly defined (including waste, by-products, residues, energy, water, logistics, capacity, expertise, equipment and materials) from another, with the result of keeping resources in productive use for longer.

Different approaches to identifying opportunities for establishing IS are used in practice:

1. **Self-organised**: a bottom-up approach resulting from direct interaction among industrial actors, without external coordination. Expertise resides within the organisations with resources and opportunities; organisations identify, assess and advance opportunities themselves.
2. **Facilitated**: wherein a third-party intermediary coordinates the activity, working with organisations to identify opportunities and help bring them to fruition. Facilitators can come from the private sector, the public sector, academia or the third sector.
3. **ICT-supported**: IS activity is supported by an ICT system to capture and manage data on resource availability and potential synergies.
4. **Strategic or planned**: a top-down approach where networks are formed following a central plan or vision that includes attracting new businesses to regeneration sites or purpose-built developments. The onus lies with the central body (often public sector) implementing the plan or vision’ (CWA- CEN WORKSHOP AGREEMENT Industrial Symbiosis).



Source: http://www.symbiosis.dk/en/

In practical terms, to get started with IS, the following steps (among others) needs to be done:

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<table>
<tr><th colspan="2">Industrial symbiosis assessment and solution pathways for facilitating cross-sectoral energy and material exchange</th></tr>
<tr><td colspan="2">Mapping energy or resource streams and their value/costs and identify opportunities.
Map all stakeholders in the process
Search (locally) for partner companies
Identify the knowledge gaps and support needs to further elaborate the opportunity.
Available tools, software and platforms both for resource-need matching and for integrated solutions planning are very important for facilitating the industrial symbiosis.

Product life cycle stages & Modules (EN15978): A1 Raw materials supply</td></tr>
<tr><td>CO-BENEFITS</td><td>Benefits from industrial symbiosis are mainly reduction of energy used and avoidance of waste. Since energy is not wasted but used by another partner in the symbiosis, (Reduce energy needs) and avoiding the generation of waste, which can be recovered to be used as feedstock for other (better waste management, Promote the materials cycle).
Reduce GHG emissions.
Local proximity is not a mandatory for industrial symbiosis but it significantly facilitates its establishment promoting proximity economy</td></tr>
<tr><td>KEYWORDS</td><td>Direct connection to instruments:
Urban metabolism mapping- identifying product streams and material inputs (in addition to waste)
Supporting municipalities to monitor resource flows in line with impact targets and measurement processes
Capacity building and engagement with municipalities to identify and co-create circular solutions and roadmaps
Capacity building for city officials to understand urban metabolisms and circular solution opportunities</td></tr>
</table>

3.5.20 Production of biofuel based on black liquor from the paper industry

- Authors: **LGI**
- Knowledge Repository link: **https://netzerocities.app/resource-2574**

Production of biofuel based on black liquor from the paper industry
Black Liquor is a **by-product of pulp from mills** that make products from trees, such as paper. It is currently used to recover cooking chemicals and produce high-pressure steam used in the pulp and paper-making process. It is composed of different ingredients from these processes such as lignin, hemicellulose, sodium hydroxide (NaOH) and sodium sulphide (Na_2S).

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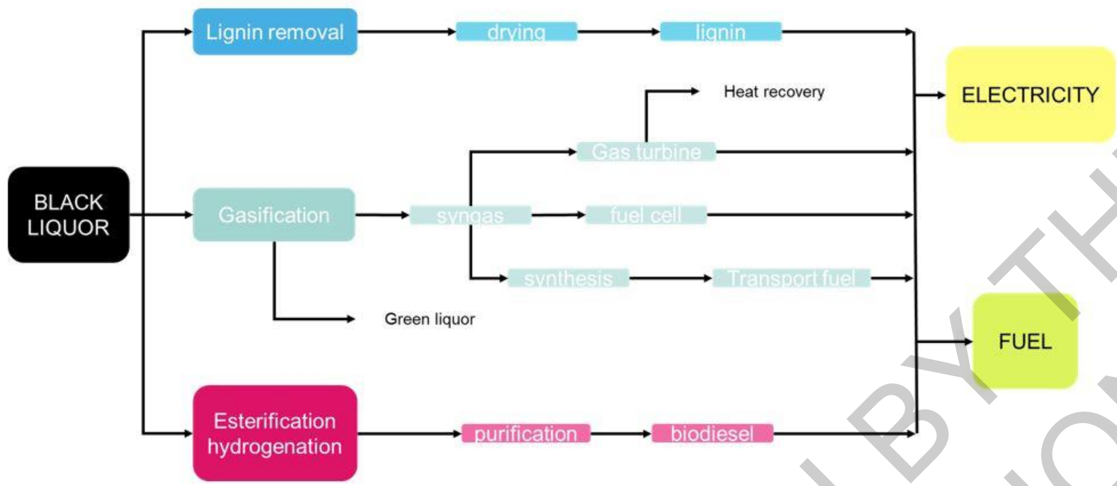
Production of biofuel based on black liquor from the paper industry



Source: adapted from Hamaguchi, M., Cardoso, M., & Vakkilainen, E. (2012). Alternative Technologies for Biofuels Production in Kraft Pulp Mills—Potential and Prospects. Energies, 53390, 2288–2309. *https://doi.org/10.3390/en5072288*

The lignin compound in black liquor can be used to make drop-in biofuel for transportation. The advantages of this sort of biofuel compared to fossil fuel and other biofuels are:

- produced from a renewable fedstock (trees),
- lower indirect land use impact than traditional biofuels made from agricultural crops,
- circular alternative for the paper industry, avoiding the landfilling of black liquor,
- lower pollutant emissions than fossil fuels.

Product life cycle stages & Modules (EN15978): Benefits and Loads beyond the Life Cycle D

CO-BENEFITS	• Reduce GHG emissions • Better waste management • Improve land use management • Reduce ecological footprint
KEYWORDS	Direct connection to **technical solutions**: • Waste-to-energy valorisation technologies
EXTERNAL LINKS	• https://www.bl2f.eu/ • *Hamaguchi, M., Cardoso, M., & Vakkilainen, E. (2012). Alternative Technologies for Biofuels Production in Kraft Pulp Mills—Potential and Prospects. Energies, 53390, 2288–2309.* https://doi.org/10.3390/en5072288

Production of biofuel based on black liquor from the paper industry	
PRE-CONDITIONS & ENABLING CONDITIONS	***Pre-condition:*** Existence of a pulp and paper industry Sustaining a value chain with a complexity of stakeholders
CONSTRAINTS/ BARRIERS for implementation	***Legal framework*** Policies promoting biofuels ***Technical barriers*** Feedstock availability Infrastructure Know-how ***Market barriers***

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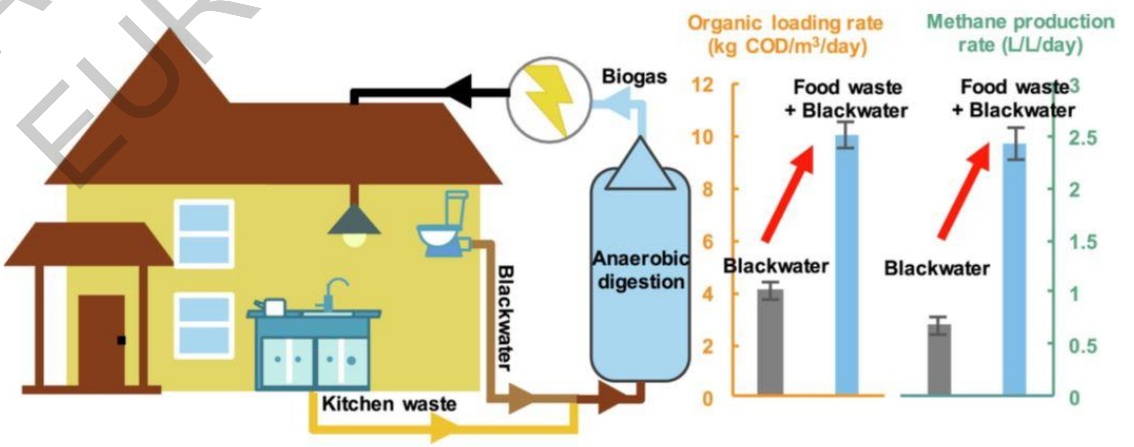
Production of biofuel based on black liquor from the paper industry	
	High cost competitivity of fossil fuels Cost competitivity of imported biofuels
INSTRUMENTS/ Processes for implementation	• Cooperatives • Supporting municipalities to monitor resource flows in line with impact targets and measurement processes • Capacity building and training • Decarbonisation Plans for Industry • Public procurement for innovative NBS and Green Infrastructure interventions • Circular Life Cycle Assessment/Analysis for material and products
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	• High production cost • Transport and logistics • Feedstock availability and stability • High maintenance
IMPACTS (Indicators & DNSH)	• GHG emissions avoidance compared to conventional alternatives • Total capital requirements per ton of output (EUR/ton) • Total annual operational costs per energy output (EUR/MJ)

3.5.21 Waste to energy in buildings

- Authors: **CARTIF**
- Knowledge Repository link: https://netzerocities.app/resource-2584

Waste to energy in buildings
Grinded Bio Waste and Blackwater (water from toilets or kitchens) generated in households can be treated in **Anaerobic Membrane Bio-Reactors** (AnMBR) for the recovery of: • **Reuse** of treated blackwater (>90%) for toilet or fertigation, • **Compost**: The sludge from the anaerobic digester can be emptied regularly to produce high-quality compost. • **Renewable energy**. Absorption technologies can be used to ensure biogas quality. The solution would also include biogas cleaning to increase CH4 content (>80%) and potential storage in inflatable and impermeable fabrics. This energy storage can be further used for potential grid injection, use in µCHP, or combustion in a natural gas boiler. This solution supports the Net-Zero-Energy Building (NZEB) or passive house claims to reach full autonomy (100%) even in winter times (December-February), when heating systems are mostly needed, and sun heating will not be easily available. In terms of biogas uses, this solution can be adapted to fit with energy, cogeneration or accumulation requirements of buildings.



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Waste to energy in buildings	
Source: Mengjiao, Gao, et al. (2020) High-loading food waste and blackwater anaerobic co-digestion: Maximizing bioenergy recovery. Chemical Engineering Journal, 394, 124911. https://doi.org/10.1016/j.cej.2020.124911 *Product life cycle stages & Modules (EN15978): C3 Waste processing + C4 Landfill + D Reuse and Recycling + D Energy recovery*	
CO-BENEFITS	• Reduce GHG emissions • Reduce energy needs • Increase access to clean, affordable, and secure energy • Proximity economy • Increase technological readiness • Better waste management • Promote the materials cycle • Better water quality • Better water management • Improvement in soil health
KEYWORDS	Direct connection to **technical solutions**: • Greywater and rainwater reuse at building level • Efficient treatment and reuse of un-segregated water at building level
EXTERNAL LINKS	• HOUSEFUL Project: https://houseful.eu/solutions/blackwater-and-bw-treatment-for-biogas-production/ • *Mengjiao, Gao, et al. (2020) High-loading food waste and blackwater anaerobic co-digestion: Maximizing bioenergy recovery. Chemical Engineering Journal, 394, 124911. https://doi.org/10.1016/j.cej.2020.124911*

Waste to energy in buildings	
PRE-CONDITIONS & ENABLING CONDITIONS	***Technical aspects / infrastructure:*** Waste to energy in buildings is implemented through different stages and with several (complex) technical requirements: • Pre-treatment stage: (1) greywater/blackwater separation in place, (2) grinding equipment for bio-waste treatment in place, (3) homogenization system, (4) odour treatment and (5) space requirement for the waste pipes. • Anaerobic Membrane Bio-Reactor (AnMBR) treatment: (1) Due to the weight of the AnMBR system the surface must be solid, flatten and levelled. • Post-treatment stage: (1) Availability of a biogas storage system and a fuel cell for biogas valorisation as energy, (2) gas piping has to be installed underground and (3) Stabilisation of digestate for final use as fertilizer in local gardening. ***Security:*** Regarding security aspects, it is necessary to use ATEX electrical installations as the system contains gas storage with biogas (flammable gas). ***Economic and social context:*** The economic feasibility of this solution is strongly linked to the scale of the anaerobic digestion process, which will depend on the number of residents/tenants and the waste production. For renovation projects, it is necessary to find consensus in multi-owner buildings. ***Regulatory framework:*** The permit from local building authorities need to include a comprehensive safety and explosion prevention concept.

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Waste to energy in buildings	
CONSTRAINTS/ BARRIERS for implementation	***Technical:*** Maintenance over long term, continuous monitoring (sensors, flowmeters and flow regulators, manometers, pressure sensors), periodic sampling and analytics. ***Policy and regulatory/legal framework:*** Compliance with current regulations regarding wastewater discharge, water reuse, management of wastes, sanitary requirements, and biogas security aspects: The EU Water Reuse Regulation. The requirement of periodic sampling is a barrier (logistically, financially, etc.) for using on-site or decentralised water treatment systems. EU wastewater discharge regulation. Obligation for sewage disposal and connection to the municipal sewage treatment plant. In places where there is no possibility to connection to a sewage system, it is suggested to have two independent systems for food waste and blackwater. EU Urban Waste Water Directive Taxes and charges for building permits can be a barrier for further implementation ***Social:*** Need of end-user engagement (tenants and residents) in renovation projects and their concern about noise or odour generation or the potential increases of the renovation costs, and thus, rents.
INSTRUMENTS/ Processes for implementation	• Local energy communities can implement this technology. https://netzerocities.app/resource-618 • Capacity building and training is required for manpower https://netzerocities.app/resource-1578 • One-stop-shop for building renovation https://netzerocities.app/resource-1913 • Instruments for incorporating innovative solutions in public procurement: EU Briefing on Innovation Partnerships: https://ec.europa.eu/docsroom/documents/47178
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	Waste to energy recovery is often done on a case-by-case basis, there is no standard solution due to very individual and site-specific boundary conditions, as well as the limited number of real-life case studies. This results in high efforts to plan, design and operate systems. Consequently, the engineering and instrumentation efforts and connected costs are relatively high compared to other energy sources. Noise or odour generation due to the AnMBR treatment can also be considered as adverse impacts of the solution.
IMPACTS (Indicators & DNSH)	Indicators [1], [2] • Removal of Chemical Oxygen Demand (COD): ≥ 90% • Organic Loading Rate: 10 to 15 kg COD/m^3d • Biogas production 0.06 to 0.382 L CH_4 / g COD • Energy production from potential methane production ≤ 0.246 kWh/m^3 CH_4
	Climate change mitigation: Waste to energy solution leads to a significant greenhouse gas emissions on a lifecycle basis. ***Circular economy**:* Reclaimed water reuse can be a major benefit for garden or agricultural irrigation, toilet flushing, street cleaning, etc.
Additional information from CASE STUDIES	LEITAT building (HOUSEFUL Project). Waste to energy is implemented by a two-stage AnMBR to treat kitchen wastes from the catering and the blackwater generated in the office building. Energy consumption: 800-900 kWh/m^3 treated

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Waste to energy in buildings	
	[1] Kanafin YN, Kanafina D, Malamis S, Katsou E, Inglezakis VJ, Poulopoulos SG, Arkhangelsky E. Anaerobic Membrane Bioreactors for Municipal Wastewater Treatment: A Literature Review. Membranes (Basel). 2021 Dec 8;11(12):967. doi: 10.3390/membranes11120967. PMID: 34940468; PMCID: PMC8703433. [2] Yisong Hu, Xuli Cai, Runda Du, Yuan Yang, Chao Rong, Yu Qin, Yu-You Li, A review on anaerobic membrane bioreactors for enhanced valorization of urban organic wastes: Achievements, limitations, energy balance and future perspectives, Science of The Total Environment, Volume 820, 2022, 153284, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2022.153284.

3.5.22 Guarantee the energy saving/production in buildings by the "Contingent approach"

- Authors: **TNO**
- Knowledge Repository link: **https://netzerocities.app/resource-2594**

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the "orange" fields of this solution, and then it has been afterwards reviewed by JRC and completed the "pink" fields, and the Knowledge Repository content has been updated with JRC's input. So, here only the "orange" fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

Guarantee the energy saving/production in buildings by the "Contingent approach"	
The '**Contingent approach**' supports the upscaling of renovation solutions by identifying the specific buildings, within the building stock, where a previously successfully applied solution can be repeated. This method uses available **GIS data** of buildings (e.g. location, size, height, building year, plot size, etc.) derived from multiple sources (e.g. land registers, statistical offices etc.). For each specific renovation solution, a machine learning algorithm is trained to identify what (combination of) building characteristics have the largest influence on the applicability of these solutions. A trained algorithm is subsequently used to identify which buildings, within the entire building stock, have the highest chance of being suitable for this renovation solution. This cluster of buildings is called a contingent. This approach is developed to support **solution providers** both in the development of renovation solutions (aiming to maximize market potential) and deployment (targeting buildings with high probability of successful application). By plotting contingents of large numbers of solutions on a map, house owners can identify relevant (i.e. applicable) solutions to sustain their house. For municipalities, this can be an **instrument to plan and operationalize energy transition plans**. Product life cycle stages & Modules (EN15978): B1 Use	
CO-BENEFITS	Support solution providers in the efficient upscaling of renovation solutions. Transaction costs and lead time reduce significantly resulting in higher productivity at lower integral renovation costs. This in the end states a large contribution in accelerating towards a climate neutral build environment.
KEYWORDS	Direct connection to **technical solutions:** • Waste to energy in buildings • Passive building design strategies: building orientation, passive heating and cooling
EXTERNAL LINKS	• Whitepaper contingentenaanpak (in Dutch): https://publications.tno.nl/publication/34637810/LIRIXX/mulder-2021-in.pdf • https://www.tno.nl/nl/aandachtsgebieden/bouw-infra-maritiem/roadmaps/veilige-en-duurzame-leefomgeving/versneld-naar-een-klimaatneutraal-gebouwde-omgeving-in-2050/

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3.5.23 Circular Food Systems

- Authors: **METABOLIC**
- Knowledge Repository link: https://netzerocities.app/resource-2604

Circular Food Systems	
As cities around the world are growing, we need to find new ways to **feed growing urban populations**. Our current linear food system is wasteful, inefficient, and resource-intensive. Roughly a third of the food produced worldwide is wasted and ends up in landfills, creating harmful greenhouse gas emissions. Cities (and their peri-urban regions) can take on a leading role in creating sustainable and circular food systems with better waste management. Closed-loop food systems not only decrease food waste and pressure on the environment. They also decrease the need for new production (food loss), leading to enhanced resource utilization reusing and/or recycling by-products of the food and feed production systems.  *Source: Metabolic Institute* To design and implement circular food systems it is important to first assess **food-related flows** going into and leaving the city. Urban Metabolism Mapping can help to better understand these flows. Another important step towards circular flows in the food industry is the implementation of **regenerative agriculture practices**. Also, in order to reduce losses, it is necessary to know how the waste is generated, either food waste or human waste. Valuable nutrients and chemicals can be extracted and then used as fertilizers, plastic, chemical or textile feedstock, food compounds, or for animal feed. *Product life cycle stages & Modules (EN15978): Full value chain*	
CO-BENEFITS	**Reduction** of **GHG emissions** and **energy needs** as a consequence of the reduced need for production. There are several co-benefits of creating circularity in urban food systems: As the circular systems create new opportunities for innovation, they can help to **boost local business** (km 0), as well as a **proximity economy**. Thereby, they also lead to **increased skill development** and improved **access to job opportunities**. Circular food systems also lead to **better waste management** by helping to reduce food waste. Specific practices such as **regenerative agriculture** also have a **positive impact on land-use, biodiversity and human wellbeing**: They can lead to improvement in **soil health** and improved land use management, species increase, pollinator increase, increased ecological connectivity, and a reduced ecological footprint.

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Circular Food Systems	
	They can also promote healthier and more attractive lifestyles and lead to raised awareness/behavioural change.
KEYWORDS	Connection to **technical solutions**: • Encompassing the full value chain of producing food for human consumption - valorisation of low value fish species Connection to **Instruments**: • Urban metabolism mapping- identifying product streams and material inputs (in addition to waste) • Capacity building for city officials to understand urban metabolisms and circular solution opportunities
EXTERNAL LINKS	• https://www.metabolic.nl/news/how-to-create-a-sustainable-bioeconomy/ • FUSILLI project (under construction a knowledge community to exchange actions in cities to improve food system): https://fusilli-project.eu/
EXAMPLES	• Milan Pilot Reflow Project: https://reflowproject.eu/blog/new-concept-food-market-boost-the-circular-transition/

Circular Food Systems	
PRE-CONDITIONS & ENABLING CONDITIONS	***Policy and regulatory/legal framework:*** A strong political and policy environment that supports the development of circular food systems and provides the necessary framework for their implementation. This might include regulations, incentives, and other policies that encourage the reduction of food waste, the use of sustainable farming practices, and the development of circular supply chains. ***Economic:*** Financial support to cover the financial losses that may arise during the transition period from highly efficient but harmful food production systems to sustainable but often labour-intensive systems. ***Funding:*** To support the development of new circular business models and fill in early-stage funding gaps. ***Infrastructure*:** Circular food systems require the reconfiguration of certain infrastructures to be able to produce, distribute and recover food waste. ***Consumer demand:*** Consumers and citizens are increasingly demanding environmentally conscious food products and more transparent supply chains
CONSTRAINTS/ BARRIERS for implementation	***Engagement and participation of industry/businesses:*** Barriers to participation could be businesses' lack of awareness of certifications and standards; lack of skills and of knowledge about circular food systems, lack of market availability and lack of affordability due to premium prices for alternative food/agricultural products. ***Economic and social barriers:*** Hesitant company culture which are currently operating in a linear system. The transition to CE requires remarkable cultural changes in company structure as well as taking on financial risks of changing to a circular method. At the same time there is a lack of know-how on how to implement a circular food system. ***Economic and social barriers:***

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Circular Food Systems	
	A change to a circular food system may entail higher food prices that will go against the decade-long decrease in food prices/share of disposable income spent on food and therefore may suffer some strong social backlash. ***Infrastructure:*** Cities are built to dispose of their waste in a linear way. Circular food system must retain food waste to extract more value and resources out of it. This requires spaces and the right technical skills.
INSTRUMENTS/ Processes for implementation	• Training • Regulations for durability, reparability and recycling in public procurement • Material passports • Certification and labelling • Awareness campaigns • Voluntary measures with stakeholders • Taxation • Bans or restrictions on single use or non-recyclable materials • Green Public Procurement
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	***Economic viability*:** The profitability of new circular models, especially in the early days of the changing the food system from a linear to a circular one may be low. Food prices could see some inflation to compensate loss in efficiency. ***Drastic cultural/societal change*:** The reconfiguration of some supply chains will lead to a change in livelihood for primary producers (e.g. less meat/animal husbandry) and may lead to turmoil e.g. the farmers protests in the Netherlands.
IMPACTS (Indicators & DNSH)	(The amount of) food produced and subsequently used within the city boundaries; (The amount of) local businesses producing for citizens within the city boundaries
Additional information from CASE STUDIES	Circular food systems: They are encouraging the shift from linear to circular, sustainable food systems, in which resources are reused, nutrients recycled, by-products reduced and what remains is reutilized. Food Future: Pilot of a circular food system in Guelph-Wellington which aims to address food insecurity issues by creating Canada's first circular food economy, reimagining how we produce, distribute, sell and consume food.

3.5.24 Encompassing the full value chain of producing food for human consumption – valorisation of low value fish species

- Authors: **VTT, CARTIF**
- Knowledge Repository link: **https://netzerocities.app/resource-2614**

Encompassing the full value chain of producing food for human consumption – valorisation of low value fish species
There is a global need to find and use **alternative protein sources** in order to improve the sustainability of the food system. While alternative proteins are studied, the easiest shift in the consumers' diet is to exchange meat with fish intake. Nevertheless, this higher consumption must be done avoiding **overfishing** and improving the current **catching processes**: fish by-catch and discards account for approx. 30% of the total world capture fisheries, which translates into approximately 30 M of tons of the available resources, not utilized for human food products. On the other hand, consumers demand for convenient seafood made easily served. These nutrient-rich under-utilized species can be recovered and subsequently used in human food products,

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Encompassing the full value chain of producing food for human consumption – valorisation of low value fish species

increasing their value. Consumers' preference is also narrowed to certain farmed fish species, i.e. salmonids, whose farming can burden natural waters systems.

Source: VTT

The solution can be to adopt a production concept (**fish farms**) that uses diverse whole (ungutted) fish as raw material for convenient palatable seafoods. This innovation leads to (i) valorisation of low value raw material, (ii) simplified logistics by a decentralised production near consumers and (iii) minimum amount of waste and reduction of water consumption and (iv) marketing alternative protein sources, which is the main single factor in halting global biodiversity loss.

This concept could be **replicated** in different cities to improve the access to fish without being close to coastal areas and avoiding transport and preservation costs.

Product life cycle stages & Modules (EN15978): Full value chain

CO-BENEFITS	• Sustainable and resilient food systems • proximity economy • Better water quality • Economic benefits • Healthier and more attractive lifestyles
KEYWORDS	Connection to **technical solutions**: • Circular food cities Connection to **Instruments**: • Urban metabolism mapping- identifying product streams and material inputs (in addition to waste) • Capacity building for city officials to understand urban metabolisms and circular solution opportunities
EXTERNAL LINKS	Nisov, A.; Aisala, H.; Holopainen-Mantila, U.; Alakomi, H.-L.; Nordlund, E.; Honkapää, K. Comparison of Whole and Gutted Baltic Herring as a Raw Material for Restructured Fish Product Produced by High-Moisture Extrusion Cooking. *Foods* **2020**, *9*, 1541. https://doi.org/10.3390/foods9111541

Encompassing the full value chain of producing food for human consumption – valorisation of low value fish species

PRE-CONDITIONS & ENABLING CONDITIONS	***Political:*** Increasing food supply security is a political hot topic in the EU. This is a momentum to adapt sustainable processing of undervalued fish for food use as these fish stocks are a sustainable and significant but under used and capitalised food raw material source. Market availability primarily in urban areas focal to raise interest more broadly. ***Economic:*** The technology adapted to commercial scale (big centralised or small decentralised - the technology bends to both) will increase the use of this fish raw material for food leading to better profits to fishermen that presently enforce management

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Encompassing the full value chain of producing food for human consumption – valorisation of low value fish species	
	fishing by the governmental subsidies to reduce nutrient loads in selected water systems. Keeping good quality of fish raw materials central to exploit economy of scale in processing. Small scale processes can be established in urban areas to maximise the benefit of the catch from nearby waters. ***Legal:*** none ***Social:*** Consumer preference of domestic diverse undervalued wild fish over to imported and farmed salmonoids. Urban aware consumers are flag wavers. ***Technological:*** Increased raw material efficiency, wet extrusion technology uses whole rather than filleted/gutted fish leading to minimum waste generation. This leads to reduction of biowaste generation.
CONSTRAINTS/ BARRIERS for implementation	***Political:*** Energy price (fuel of fish trawling vessels, energy for processing). ***Social:*** Vast majority of European and Finnish consumers prefer convenient salmon fillets. ***Technological:*** fish raw materials may necessitate another protein source to be co-extruded, preferable plant-based for sufficient textural attributes. This may affect the price of the final product. ***Legal:*** none ***Economic:*** extrusion equipment can be too investment intensive for start up's and SME's, which may hinder the broader implementation of the technology. Fish raw material per se is cheap.
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	***Economic:*** Insufficient and uneven availability of fresh fish catch prevents enterprises to run their processes in full capacity. Unpredictable and volatile price of energy weakens investment willingness and may keep fishing vessels on shore reducing catch amounts and consequently income of fishermen. Pea protein isolate used to give texture to the product is an expensive component in the final product and major carbon footprint comes from it. The process is profitable in different scales, e.g. profit of about 30 % is obtained with capacity about 300 tonne fish/year when the product price is 5 €/kg and process runs in full capacity. ***Environmental:*** Water warming (climate change) and microplastic etc. pollution in the longer perspective leads to imbalance of aquatic ecosystems and shifts of wild fish stocks. The solution does not affect the land use, but affects positively to the nutrient levels of inland lakes.
IMPACTS (Indicators & DNSH)	INDICATORS: • CAPEX: under assessment (big, medium, small scale) • OPEX: under assessment (big, medium, small scale) • Carbon foot print (LCA) 1.1 kg CO_2e/kg. 75% emissions come from pea protein production (an additive, usage of which is to be reduced), 13% energy and 12% from fish trawling
	DNSH: No negative impacts

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Encompassing the full value chain of producing food for human consumption – valorisation of low value fish species	
Additional information from CASE STUDIES	Nisov, A.; Aisala, H.; Holopainen-Mantila, U.; Alakomi, H.-L.; Nordlund, E.; Honkapää, K. Comparison of Whole and Gutted Baltic Herring as a Raw Material for Restructured Fish Product Produced by High-Moisture Extrusion Cooking. *Foods* 2020, *9*, 1541. https://doi.org/10.3390/foods9111541

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3.6 Nature-based Solutions and Carbon sinks

- **Knowledge Repository: Nature-based solutions**: https://netzerocities.app/resource-2644

Table 8: Nature-based Solutions (NBS) solutions

Nature-based Solutions		Section
Urban carbon storage and sequestration, and singular green infrastructure	Urban carbon sink	3.6.1
	Smart-soils and phytoremediation	3.6.2
	Pollinator and verges spaces	3.6.3
	Vertical mobile gardens	3.6.4
	Green shading structures	3.6.5
	Floating gardens	3.6.6
	Green filter area	3.6.7
	Urban garden bio-filter	3.6.8
	Green resting areas, parks and urban forests, parklets	3.6.9
	Cooling trees	3.6.10
	Green corridors for active and cooler mobility	3.6.11
	Community composting	3.6.12
Water interventions	Hard drainage-flood prevention	3.6.13
	Grassed swales and water retention pounds	3.6.14
	Floodable park	3.6.15
	Green pavements: hard drainage pavements; green parking pavements	3.6.16
	Sustainable Urban Drainage Systems (SuDS)	3.6.17
	Water irrigation and maintenance technologies	3.6.18
	Constructed wetland	3.6.19
	Rain garden	3.6.20

3.6.1 Urban carbon sink

- Authors: **South Pole**
- Knowledge Repository link: **https://netzerocities.app/resource-1128**

Urban carbon sink
Cities are amongst the biggest contributors to carbon emissions because of widescale urbanisation, while also being highly vulnerable to resultant impacts of these emissions due to climate change impacts. Solutions that **reduce or capture more carbon emissions** than they release are called carbon sinks. **Urban carbon sinks** refer to a combination of solutions focused on **maximising carbon capture and sequestration** through the plantation of **particular trees in urban and peri-urban green spaces**, alongside existing or planned infrastructure. The solution can be combined with other solutions such as biochar production from green areas and garden waste to enhance carbon sequestration. Selecting tree species and managing the sink across the tree lifecycle is key to achieving the end objective of carbon sequestration. The focus should be on **native species**, which need minimal resources and have high survival rates.

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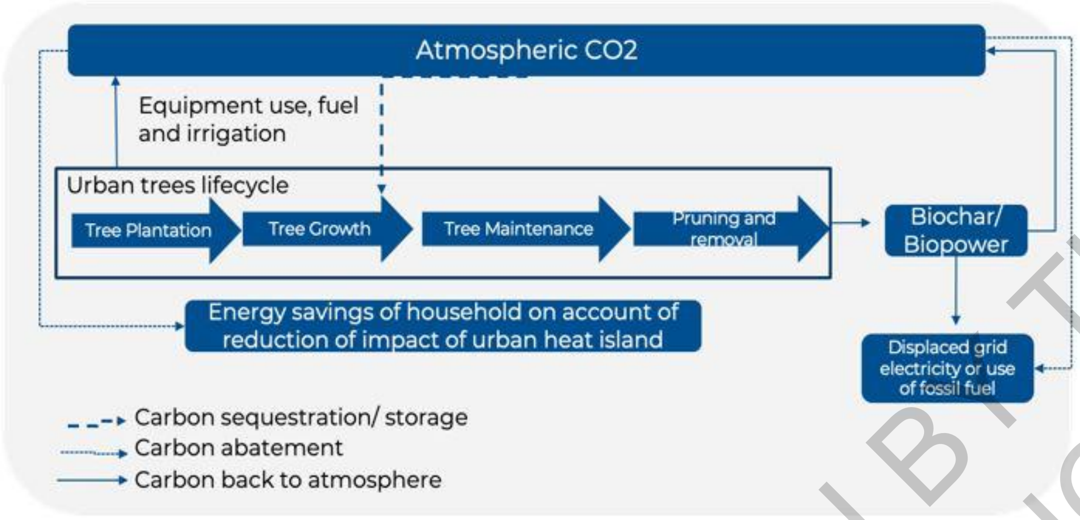
Urban carbon sink	
 Urban carbon sink can be well **integrated** as a strategic approach while **planning and developing urban green spaces**. Cities may introduce a policy framework outlining appropriate tree species, financing and incentive models, and operating model for development of urban green spaces (e.g. parks, parklets, urban forests, private green areas). Apart from maximising carbon sequestration, urban carbon sinks have numerous direct benefits such as **reducing effect of urban heat island effect** by increasing shadow surface and **improving air quality** through the removal of harmful gases and particulate matter from atmosphere. Additionally, these green spaces also provide many ecosystem benefits such as improving human health and well-being, regulating storm water infiltration, enhancing biodiversity in the area, improving economic value and creating livelihood opportunities for local community, recreation and nature education among others.	
CO-BENEFITS	• **Improved air quality**: Plants are a great resource for removing air pollutants and smog from the atmosphere, and protecting from harmful UV rays; • **Improved human health and enhanced citizen participation, connectivity, and sense of community**: these spaces create a green space network and support busy city life, improving health, prosperity, and happiness of citizens; • **Enhanced biodiversity and pollinator increase**: with enhanced green areas, an instant improvement in biodiversity is observed. This contributes to soil moisture content enhancement and improved nutrient cycle, thereby impacting the surrounding flora and fauna; • **Enhanced green mobility**: urban sinks offer aesthetically green spaces to move around in the built concrete spaces; • **Increased carbon sequestration**: green areas increase the absorption of carbon dioxide and increase the supply of oxygen; • **Reduced hotspots and urban heat island impact**: trees and plants reduce the impact of urban heat island effect as they create a cooling effect around them; • **Enhanced attractiveness of the cities**: green areas create aesthetically beautiful environment in the cities which further beautifies the city. Urban carbon sinks can create an interconnected network of green spaces that sparks interest in citizens and harmonizes the negative impacts of urban expansion; • **Green awareness**: improved awareness amongst citizen of native tree species and the value of trees; • **Reduced noise pollution**: trees can reduce noise level by human ear by more than 50%; and • **Economic opportunities**: by leading to enhanced land prices for the properties in proximity.

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Urban carbon sink	
KEYWORDS	Urban carbon sink is linked to solutions such as cycle and pedestrian green route, cooling trees, other singular green infrastructure solutions, water intervention, environmental awareness, etc.
EXTERNAL LINKS	• NBS Catalogue [*pages 101-102*] • Urban Carbon Sink in URBAN GreenUP catalogue [*Pages 58-60*] • Choosing the right nature-based solutions to meet diverse urban challenges • Compendium of Nature-based and 'grey' solutions to address climate- and water-related problems in European cities (GrowGreen project) • Green Resting Areas (URBAN GreenUP project) • NBS Handbook (Think-Nature project) • Addressing climate change in cities, NBS catalogue • https://www.ecologic.eu/sites/default/files/publication/2020/addressing-climate-change-in-cities-nbs_catalogue.pdf • Nature and net zero: Why investing in nature is important (World Economic Forum) • Approaches to financing nature-based solutions in cities (GrowGreen project) • Designing for biodiversity in low carbon and net zero buildings (UK)
EXAMPLES	• Helsinki, Finland, Case Study

Urban carbon sink	
PRE-CONDITIONS & ENABLING CONDITIONS	Urban carbon sink is an integrated approach towards developing urban nature-based solutions, with an objective to store carbon emissions as well as provide a slew of ecosystem services. ***Climate and Geography:*** Urban forests and urban green spaces can be planted anywhere adapted to the local tree species, which should be selected according to hardiness zone, soil type, sunlight and rain data, frost schedules and other factors that affect the success of trees and vegetation, as well as carbon sequestration potential. In terms of soil conditions, sandy and loamy soils provide better conditions for new forests given their strong infiltration capacity and aeration of the soil. In addition, different sizes and their interaction with each other will be considered in order to favour the planting framework for optimum growth and new ecosystem formation, ***Urban form and layout:*** Urban green cover can be planned along infrastructure networks, residential streets and large-scale infrastructure – highways and rail tracks are suitable for linear urban green cover. Urban forests can be planned in degraded natural forest areas, alluvial sites along water bodies, steep slopes at risk of soil erosion and landslides, non- productive agriculture and industrial wood plantation sites in peri-urban areas. ***Technical aspects/infrastructure:*** The planning of urban carbon sinks should be holistic and integrated with urban planning and city climate action plans. These green areas should become an integral part of conservation zones and in the development of green areas and public parks. The following key technical aspects should be taken into consideration. • **Slope:** direction of slope is a key factor during the incubation period of trees. • **Site preparation:** may be required in terms of removal of weeds, augmentation of soil structure, or irrigation provision. • **Species selection:** given the objective of urban carbon sinks is to sequester carbon alongside ecosystem benefits, the planting and growing

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Urban carbon sink	
	strategy should be prepared in consideration of the most suitable local tree species. Also, the focused-on C fixation capacity, easy management, aesthetics, health and ecological coherence and integrity criteria • **Seedling and tree production:** the best strategy should be selected depending on local context – in some cases, planting of large sampling instead of conventional seedling can be more preferable. The availability of a nursery is crucial for quality samplings. • **Planting and growing strategy:** A sustainable strategy is required to consider human and land management practices in urban contexts. In case of plantation in degraded land, well-watered sturdy plants from nurseries are required. Urban forests or green cover planned alongside gray infrastructure often require additional considerations for seedlings, tree size, pre-planting, formative pruning and root management. • **Time of planting:** seedlings should be planted at the right time of year, in consideration of the local weather considerations related to precipitation. • **Green waste management:** including timely pruning and conversion of waste from pruning into compost or biochar. Cities should develop an urban carbon sink strategy and action plan with a localised approach which considers the factors outlined above, along with a robust institutional and governance framework to ensure on-ground implementation. ***Policy and regulatory/legal framework:*** The urban carbon sink should be well-integrated into urban planning principles and should be implemented through a holistic strategy – supported by a policy framework, spanning across different departments from parks and recreation to utilities. Policies along with guidelines can outline the creation and management of urban carbon sinks (including the appropriate species and techniques) as a critical element to be included in planning grey infrastructure, defining land uses, as well as planning resilience in cities. Regulations mandating private sector support for greening activities in public infrastructure – as well as private sector developments in form NBS and green infrastructure ordinances in local development and building by-laws – can create an enabling environment for holistic development of urban carbon sinks in the city. ***Funding and Financing:*** Urban carbon sinks in public places can be primarily financed through a city's own resources. These resources can be blended with private sector funding initiatives such as CSR funding, advertisement/ naming rights and ecosystem benefit charges. Monetisation of the environmental attribute can also be a potential funding model. Cities might introduce schemes such as gift-a-tree to enhance community participation. Access to EU/public funding and innovation procurement can further incentivise the development of urban carbon sinks. For instance, the Interreg project URBforDAN, where more information on funding and best practices was obtained through participation in multi-stakeholder dialogues at EU-level. ***Economic and social context:*** It is very important that citizens and the local community are aware of the public value of urban carbon sinks and greening. Urban citizens and elected officials must understand the full range of services trees and green space provide to properly plan and manage urban carbon sinks, including urban forests and urban green spaces. Therefore, it is important to spread awareness of a Nature-based approach that will reduce emissions emitted due to the degradation of forests. Implementing NBS for a carbon sink would aid in resolving social issues and provide ecosystem services that are beneficial to human well-being and biodiversity. This can be done through educational activities on NBS, city coaching in NBS, monitoring impact and reporting the ecosystem benefits of NBS (refer instruments below for more details). ***Project Governance and Implementation modalities:***

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Urban carbon sink	
	It is critical projects be implemented and monitored at a central-level in the city as a part of climate action and resilient planning. The implementation may follow three sub steps. • Forest/ Green cover assessments: Type mapping of natural area, stand assessment, protective modelling and vision setting • Planning and policy: development of city-scale green policy, planting and management goals and sub-area specific goals • Management actions: Implementation plan and strategy development for conservation and new plantation assigned to a specific agency or a third-party. Monitoring and Verification through mapping of trees and biannual monitoring of growth.
CONSTRAINTS/ BARRIERS for implementation	***Climate and geography:*** Afforestation must be implemented with due diligence in dry climates to avoid any impact on water tables. In areas where water is critical to tree growth, artificial irrigation may be required to sustain the forests. Soils with a high proportion of clay and compact soils are much less favourable to the establishment of new roots. In semi-arid and arid climates, special considerations regarding water needs, irrigation, and the impacts of establishing green corridors on water tables and soil recharge rates should be evaluated prior to implementation. ***Urban form and layout:*** The urban environment results in challenging conditions for tree growth due to exposure to pollutants, high temperatures, limited space above and below ground and increased susceptibility to insects and diseases. ***Technical aspects/infrastructure:*** Given the challenging condition outlined above, proper planning and strategy development is key towards successful implementation. Maintenance is key to realise the benefits of urban carbon sink, particularly in the first 5 years. Tree seedlings may require watering or irrigation and need to be protected from weeds competing for light, moisture, and nutrients, and from grazing wild and domestic animals. Pruning and cutting may also be required. As maintenance is a manpower- and resource-intensive exercise – and dependent on ownership and responsibilities of departments – it can become a key constraint. Innovative maintenance models, including communities, incentive mechanisms and regular monitoring with contractual obligation, can be used to overcome this barrier. Innovative procurement techniques for development and maintenance of urban carbon sinks can be used, involving local communities and the private sector for implementation. ***Policy and regulatory/legal framework:*** Some policies may have negative impacts on urban carbon sinks. For instance, policies related to design of roads and sidewalks that fail to provide adequate space for roots and tree canopy. National and regional policies that guide urban expansion planning and development should include urban carbon sink as a key design element. ***Economic and social context:*** The component of urban carbon sinks i.e. urban trees and urban forest are often considered a financial burden or risk, as ecosystem benefits are poorly understood and may not be fairly valued by citizens, communities and decision-makers.
INSTRUMENTS/ Processes for implementation	• Educational activities on NBS: https://netzerocities.app/resource-1518 • Supporting municipalities to monitor resource flows in line with impact targets and measurement processes: https://netzerocities.app/resource-1528 • Engagement, co-creation and co-design of NBS and Green Infrastructure plans and interventions: https://netzerocities.app/resource-1608 • City coaching in NBS: https://netzerocities.app/resource-1618

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<table>
<tr><th colspan="2">Urban carbon sink</th></tr>
<tr><td></td><td>Platform for Enhancing Multi Stakeholder Dialogue to Implement NBS across EU: https://netzerocities.app/resource-1628
Integrated climate plans for cities (i.e. SECAPs): https://netzerocities.app/resource-1698
Public procurement for innovative NBS and Green Infrastructure interventions: https://netzerocities.app/resource-588
NBS and Green Infrastructure regulation and ordinances: https://netzerocities.app/resource-1813
NBS and Green Infrastructure plans and strategy design and governance: https://netzerocities.app/resource-1823</td></tr>
<tr><td>DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation</td><td>Climate and Geography:
In cities where seasonally, dry climate forest fire poses a significant risk, timely rational maintenance pruning and an effective fire prevention strategy is essential. In absence of these, the solution may result in an increase in overall emissions. Dead seedlings should be replaced early in the following rainy season, ideally with seedlings of a similar size to those surviving nearby.

Economic and social context:
The plantation and maintenance activities are resource- and capital-intensive, and the success rate is largely dependent on monitoring and active maintenance. Hence, investments made by the city in urban carbon sinks can only be justified if the value of the associated ecosystem services is captured and communicated.

Technical aspects:
Given that urban carbon sinks are generally dependent on regional precipitation and water balance, they are more vulnerable to extreme climate events. The strategy and action plan for urban carbon sinks should therefore take into consideration their vulnerability to extreme climate events.</td></tr>
<tr><td rowspan="2">IMPACTS (Indicators & DNSH)</td><td>Emissions Carbon Storage and Sequestration:
Urban forestry can offset 18.57% of the carbon emitted by urban industries and store 1.75 times the annual carbon emitted by city energy use. (Urban Forestry | Climate Technology Centre & Network | Tue, 11/08/2016)

Energy Consumption:
Trees can cut 40% of residential and commercial building energy use due to their cooling impact.

Clean Air:
Urban carbon sinks purify the air by removing NO2, O3, SO2, and PM10 particles, resulting in improved lung health of citizens.

Flood risk reduction:
Well-managed urban carbon sinks can retain stormwater and decrease the risk of urban flooding.

Cost:
Capital cost for afforestation (planting, establishment and financing): EUR 15,000–19,000/ ha (Cambridge Econometrics 2020).</td></tr>
<tr><td>DNSH:
Forest fire resulting from extreme heat and climate change events can pose a significant risk on urban forests, resulting in impacts on the following environment objective:
Climate Change Mitigation: Release of carbon back to atmosphere
Pollution prevention and control: Release of harmful gases can impact the local air quality significantly</td></tr>
<tr><td>Additional information</td><td>Forest Carbon Sink Resource Asset Evaluation with Case Study of Fujian Province in China</td></tr>
</table>

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Urban carbon sink	
from CASE STUDIES	Carbon sink asset evaluation methods must mature as the forest carbon sink market matures and trading information opens. In this paper, asset appraisal basic, market method, cost method, and income method were used to study forest carbon sink value. Asset appraisal related economic and technical means were used to confirm forest carbon sink savings, which is the basis of its economic value. ***Co-Designing Urban Carbon Sink Parks: Case Carbon Lane in Helsinki*** Municipalities worldwide must adopt negative emission technologies to achieve carbon neutrality in 20 years. This paper examined the main principles of urban demonstration areas using trees and biochar for carbon sequestration and found that demonstration sites of urban carbon sinks in public parks must be safe, visible, and scientifically-sound for reliable and cost-effective verification of carbon sequestration. Toronto Strategic Forest Management Plan, 2012–22 The City of Toronto recognises the value of urban forests and aims to increase its tree canopy cover to 40%. The City's focus is on maximising the potential ecological, social, and economic benefits of urban trees. The Urban Forestry branch of the Parks, Forestry and Recreation division maintains over four million trees on public property and works with local groups and residents to expand and improve the urban forest throughout the city. Since 2013, the city has been planting approximately 100,000 trees on public lands – parks, streets, ravines – per year, with ambitions to increase that to 300,000 trees per year through new private–public partnerships with private landowners. ***Urban Food Forest Rijnvliet, 2017–ongoing*** Residents of the Rijksstraatweg and the Metaalkathedraal areas proposed the concept of a food forest in the new urban development of Rijnvliet in 2017. The municipality developed a public space for this purpose – the edible residential area. All plantings were chosen for their value to nature, with strong preferences for edible plants and trees, even in the private residential gardens. The municipality has also accorded Rijnvlie a central food forest of 15,000 m2, dedicated space built on seven multiple layers that form an integrated ecosystem. A neighborhood orchard for recreational activities and play areas for children is also in planning. Residents, the school, and the municipality regularly discuss fresh ideas to implement. ***The Green Belt of Vitoria-Gasteiz Spain, 1990s–2008*** The Green Belt is a group of peri-urban parks of high ecological and landscape value, strategically linked by eco-recreational corridors. It is a result of an ambitious environmental restoration project initiated in the early 1990s around the outlying areas of Vitoria-Gasteiz with the objective of creating a large, green area for recreational use around the city. It offers many different environments with a wealth of natural features. Woods, rivers, wetlands, meadows, fields, groves, and hedgerows are some of the varied ecosystems that coexist. Some of these ecosystems, such as the restored wetlands of Salburuaor and the River Zadorra ecosystem, have won recognition at international level for their high environmental value. ***Challenges facing Melbourne Urban Forests***

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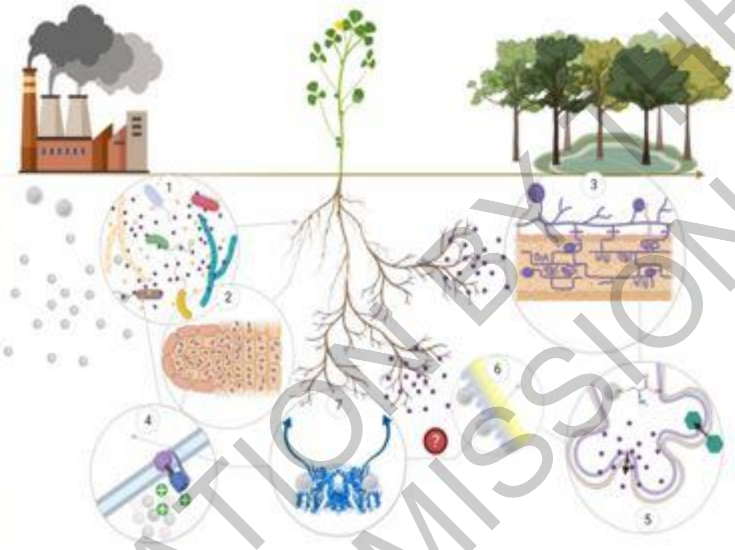
3.6.2 Smart-soils and phytoremediation

- Authors: **METABOLIC**
- Knowledge Repository link: **https://netzerocities.app/resource-1158**

Smart-soils and phytoremediation

Healthy soil can serve as a vital **carbon store**. **Climate-smart soil management** is therefore crucial and can help to make agricultural practices more resilient to the consequences of climate change. Innovative technologies can improve fertility and soil biodiversity as well as reduce risks for erosion. Conservation agriculture practices such as minimum soil disturbance, permanent soil cover, and crop rotation also help to prevent carbon being released from the soil into the atmosphere.



Phytoremediation is an approach to cleaning up contaminated soil. Living plants remove pollutants such as heavy metals in the soil by extending their root system. The approach is eco-friendly, economically feasible, and easy to implement. Next to improving the **soil quality by absorbing pollutants** and releasing valuable nutrients into the soil, it can also help to prevent soil erosion. Advances in genetic engineering can improve plant performance and generate specific plants that grow quickly and are particularly efficient in extracting toxins from the soil. Phytoremediation is especially suitable for revegetation attempts in urban brownfield land such as former industrial areas. By regenerating the soil, it also contributes to increased biodiversity in cities.

CO-BENEFITS	Next to contributing primarily to the **improvement in soil health**, smart soil management has several co-benefits. It contributes to greater **biodiversity**, specifically to species increase and **pollinator increase**, and in increase in **ecological connectivity**. Conservation agriculture practices can help to **reduce GHG emissions** and **improve air quality**. Lastly, revegetation attempts in urban brownfield land **enhances the attractiveness of the cities**.
EXTERNAL LINKS	• Phytoremediation - FoodE / De Ceuvel
EXAMPLES	• Spring Valley Arsenic Phytoremediation, Washington DC (US)

Smart-soils and phytoremediation	
PRE-CONDITIONS & ENABLING CONDITIONS	***Climate and geography:*** This solution is overall use in small green parts in urban areas where due to the high concentrations of pollution is needed to absorb stabilize or exhaust them. This is possible thanks to the use of certain plants that use in their metabolism the components that we want to reduce, so it is necessary to take into account the climate and geography in order to use the right plants, which can withstand the climate for the necessary time, and which do not become invasive. ***Policy and regulatory/legal framework:*** Long-term policies which benefit the use for smart-soils and phytoremediation over less sustainable and toxic use of soils

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Smart-soils and phytoremediation	
	Economic: Financial support to cover the financial loss as a consequence of choosing a sustainable but time-intensive solution over a harmful but quick solution. For instance, a financial incentives program for soil regeneration practices (including in extreme cases phytoremediation). ***Economic and Social context:*** Reduction of pollutants due to smart-soils and phytoremediation reduce also it in water flow cleaning the rain water and reducing the contamination in undergrow water, water reaching rivers and urban wastewater treatment plants.
CONSTRAINTS/ BARRIERS for implementation	***Insufficient incentives:*** Since these cleaning processes can take up to a couple of years, land developers often choose to use another method of cleaning since they want to use their land as soon as possible. Choosing for this option will mean losing out on potential profit without having any economic incentives to taking the time to regenerate the land first. ***Economic:*** lack of funding/investor interest and economic incentives for phytoremediation-based businesses ***Technical:*** Lack of understanding of the phytoremediation method among professionals. There is a general lack of knowledge of what types of plants align with what type of compounds and type of soils as well as it requires soil analysis and expertise in multiple domains e.g. agronomist, toxicology. ***Legal:*** Regulations inhibiting the development of genetically engineered plants that are specifically efficient at extracting toxins from the soil, lengthy environmental impact assessments that make it difficult to get modified plants to the market
INSTRUMENTS/ Processes for implementation	• Training • Incentives • Voluntary measures with stakeholders • Green Public Procurement • Engagement, co-creation and co-design of NBS and Green Infrastructure plans and interventions: https://netzerocities.app/resource-1608 • Integrated land use and urban planning with energy and climate: https://netzerocities.app/resource-1678 • NBS and Green Infrastructure regulation and ordinances: https://netzerocities.app/resource-1813
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	***Duration:*** A serious limitation of phytoremediation is the long time required for the clean-up of a site, which will take several growing seasons. In some cases, 18-60 months may be needed for site closure (source). ***Economic viability:*** Due to the long duration of cleaning the soils there is no real business model in using smart soils and/or phytoremediation. It is simply cheaper (as it is faster) to dig up the polluted soil (and replace it with clean soil).
IMPACTS (Indicators & DNSH)	***(Increased) Soil health:*** Cleaning up soil using phytoremediation increases the nutrients in the soil whilst it also can help soil erosion.
	Longevity: A clean soil with more nutrients can be used longer and in a more sustainable way for agricultural purposes.

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Smart-soils and phytoremediation	
Additional information from CASE STUDIES	***Smart soil technologies:*** For the majority of human history, food production has been solely driven by farmers. With exponential population growth, nature has been depleted of vital resources and polluted with toxic materials. By creating smart agricultural technologies that prevents and reverses these negative impacts, we can bring nature back to life to feed the world while caring for the environment. ***Ecolotree:*** Ecolotree is an Iowa-based engineering company that designs, installs, and maintains engineered forests at regulatory-permitted sites. It uses phytoremediation to remove pollutants from the soil. ***De Ceuvel:*** The soil between our boats is cultivated and maintained as a Zuiverend Park (Purifying Park): a green environment that grows specific sets of plants, which absorb, stabilize or exhaust high concentrations of pollution.

3.6.3 Pollinator and verges spaces

- Authors: **CARTIF**
- Knowledge Repository link: **https://netzerocities.app/resource-1178**

Pollinator and verges spaces
Verges spaces are empty spaces that together add up to a large area with the potential to be used for **pollinator** (Diptera, Lepidoptera and Coleoptera) promotion, which requires management guidance to determine the floral species as well as provision to reduce collisions with vehicles. Providing shelters for pollinators is strategic as they often nest in fallen tree trunks, rocks or the ground usually removed by human activity.

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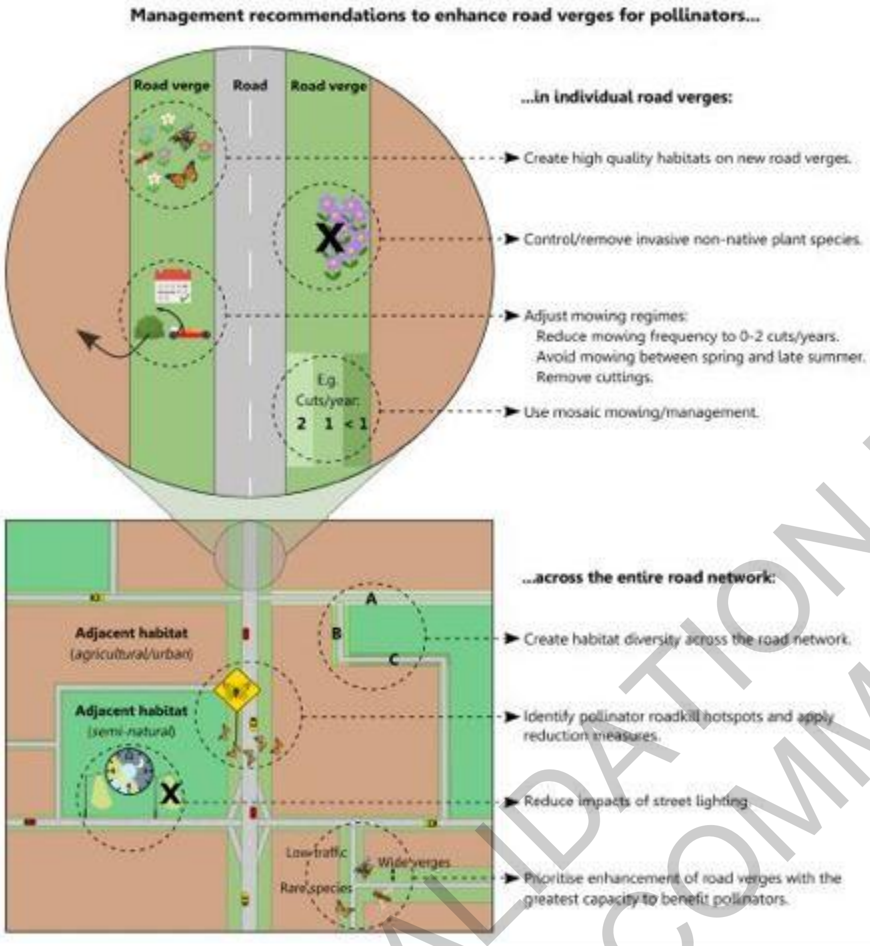
Pollinator and verges spaces	
 *Management of road verges for pollinators* In addition, in many of these areas, the use of herbicides and pesticides is prohibited (natural parks, nearby streams) and many are located in rural areas close to crops. The creation of these sites is necessary to halt the decline of pollinators and **improve the profitability of crops**.  *Source: https://highways.dot.gov/public-roads/september-2017/save-bees-and-butterflies*	
CO-BENEFITS	The positive aspects are the creation of habitats and corridors essential for the **increase of pollinators**, stopping their decline, increase of plant species and pollinators are essential for food production and these spaces for the refuge of predators of natural pests. The **negative aspect** are roads that cause vehicle-pollinator collisions, pollution, barrier to movements but can be reduced with good management, as benefits of verges to pollinators greatly exceed costs.

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This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

Pollinator and verges spaces	
	Main co-benefits that this solution can provide are: Sustainable and **resilient food systems**, Improve **land use management**, **Species increase**, Pollinator increase, Increase ecological connectivity, Reduced risk of epidemics, Reduce ecological footprint and **Green awareness**.
KEYWORDS	Pollinator and verges spaces are directly related to solutions such as urban water cycle, rainwater management and retention, urban carbon storage and sequestration solutions, and water interventions, as well as all plant-based (NBS) solutions.
EXTERNAL LINKS	• Technical Manual for Maintaining Roadsides for Pollinators • Public Roads - Save the Bees and Butterflies (conservation of pollinators)

Pollinator and verges spaces	
PRE-CONDITIONS & ENABLING CONDITIONS	***Climate and Geography:*** Pollinator spaces can be implemented anywhere, preferably using autochthonous flora with different flowering periods an overall adapted to the space and especially taking into account the conditions at the site where the plants will be located, i.e. paying attention to hardiness zone, soil type, sunlight and rain data, frost schedules and other factors that affect the correct development of plants. ***Urban form and layout:*** Pollinator and Verges spaces are able in empty spaces formed between infrastructures created as fragmentation of open spaces as impact of urbanisation reused for biodiversity conservation. Increased fragmentation of green in urbanized areas can reduce intra- and inter-species connectivity and lead to a loss of biodiversity (Kettunen et al., 2007). ***Technical aspects/infrastructure:*** A Green Infrastructure approach, linking parks and other green spaces, is therefore considered essential for the preservation of biodiversity and to counter further habitat fragmentation and increase connectivity (Sylwester, 2009). ***Policy and regulatory/legal framework / Funding and financing:*** In the EU it can be found within the European Green Deal and the Common Agricultural Policy. It also falls within the Parks and Gardens competences of the different institutions. ***Economic and social context:*** Pollinators play a very important role in society and in the economy, not only to produce honey, but also for the reproduction of many wild plants and for the improvement of the production of many crops, both for human consumption and for animal feed, which is then consumed by humans. ***Project governance and implementation modalities:*** This infrastructure can be of any size from a few centimetres to kilometres, can be placed horizontally or vertically, on rooftops, on roundabouts in the middle of the city or on highways and rail tracks. These zones can also be designed to restore a degraded area as well as to prevent soil erosion and landslides or to reclaim degraded agricultural land.
CONSTRAINTS/ BARRIERS for implementation	The belief that pollinators are undesirable insects causes them to be mistaken for pests, and they are unaware of the different stages of growth, such as caterpillars to form butterflies, eggs and different forms of ladybirds, among others.

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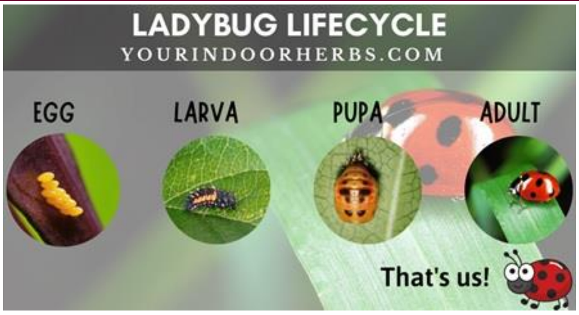
Pollinator and verges spaces	
	 *Ladybug lifecycle. Source: yourindoorherbs.com* Some of the actions to protect pollinators is not to mow so that some believe it is a neglected space There is also the problem of space, they must be able to connect with each other with less than 1 km of separation so that the smaller pollinators can move around, so it is necessary to install numerous and different: trees, planters, among others; always with the right conditions of light, soil, etc This leads to the problem that some of them need an irrigation system for plants and water sources for pollinator
INSTRUMENTS/ Processes for implementation	Educational activities on NBS, Educational/ Capacity building barriers identification: The word pollinator is often understood to mean a stinging insect, so the word "pollinator" is often used to mean an insect that stings, it is better to use names referring to flowers and plants, as the implementation is about increasing the density of autochthonous nutritious flowers. Capacity building for city officials to understand urban metabolisms and circular solution opportunities: The European Environmental Programme States that in 2020 "Cities in the Union are implementing policies for sustainable urban planning and design" "that asses the environmental performance of cities considering economic, social and territorial impacts". NBS Engagement, co-creation and co-design of NBS and Green Infrastructure plans and interventions: Incentives, Citizen participation, spaces for knowledge and co-creation: Final users need to understand these actions to accept it and be part of them with active participation (planting or sowing). NBS and Green Infrastructure regulation and ordinances: Sanctions, reduce acts of incivility by people tearing up plants, using them as ashtrays or dustbins, among other actions. Integrated land use and urban planning with energy and climate: Pollinator avtions are in an urban environment an innovative way to meet urban environmental and sustainability policy targets.
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	Europe, in special Spain, has a huge variety of insects, most of them pollinate crops and wild plants. Pollinators are essential for healthy food and nature so is close to our better wellbeing. However, deforestation, pollution and other man-made problems have caused that population of wild-insect pollinators such as bees, butterflies, hoverflies and moths have dramatically declined. (IPBES, 2016; Potts et al., 2010; Vanbergen et al., 2013) Pollinator spaces can offer much-needed habitat for pollinators, providing food, shelter, and connections to other patches of habitat, for instance, roadsides is a significant conservation opportunity.

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This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

Pollinator and verges spaces	
IMPACTS (Indicators & DNSH)	It is difficult to measure the impact of NBS for pollinators as it depends very much on their size, location and composition, as well as their maintenance, and it is impossible to give a numerical value, but it is possible to say that the increase of green areas with autochthonous flowering plants has a direct positive impact. Pollination in food system is **valued** between €153 and 505 billion per annum worldwide (Gallai, Salles, Settele, & Vaissiere, 2009; Lautenbach, Seppelt, Liebscher, & Dormann, 2012). Insect pollinator conservation is asociated with **public engagement** in no-honeybees (Bhattacharyya, Acharya, & Chakraborty, 2017; Schonfelder & Bogner, 2017; Sumner, Law, & Cini, 2018; Wilson, Forister, & Carril, 2017) For pollinators, local vegetation attributes such as richness and the abundance of flowers are very important, often it is more important than the surrounding landscape (Bergman et al., 2008; Pardee and Philpott, 2014) For pollinators, the continuity of food resources over time is extremely important. The availability of suitable, flowering food plants throughout the growing season can enhance the survival, development, and reproduction of these beneficial insects (Bowers, 1986; Lehtila and Syrjanen, 1995; Kearns and Inouye, 1997; Vaudo et al., 2015).
Additional information from CASE STUDIES	• Pollinators' modules in Valladolid (Spain): https://www.urbangreenup.eu/solutions/natural-pollinators-modules.kl • Ireland Pollination Plan: https://pollinators.ie/ • Butterfly conservation: https://butterfly-conservation.org/ • Pollinator partnership: https://pollinator.org/

3.6.4 Vertical mobile gardens

- Authors: **CARTIF**
- Knowledge Repository link: **https://netzerocities.app/resource-1188**

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the "orange" fields of this solution, and then it has been afterwards reviewed by JRC and completed the "pink" fields, and the Knowledge Repository content has been updated with JRC's input. So, here only the "orange" fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

Vertical mobile gardens
Vertical mobile gardens are a type of vertical garden that are **self-supporting**. It does not need to be supported by any auxiliary element, and it can be installed or moved to different places in the city.

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Vertical mobile gardens	
 *Vertical Mobile Garden. Source: URBAN GreenUP (H2020 Project GA No 730426) and Valladolid City Council* The vertical mobile gardens have a metal structure that supports the **substrate and the irrigation system**. The substrate serves to set the roots and provide the water and the necessary nutrients. The own irrigation system guarantees the water contribution and vegetation development. This irrigation system must be connected to the water supply network. The excess water can be discharged to the public road or to the sewerage network. The panels of vertical mobile gardens may include **other cooling devices**, such as solar fans. These machines are configured to force air circulation from outside to inside the vertical garden; then they expel it at a lower temperature.	
CO-BENEFITS	This nature-based solution contributes to **reduce hot spots** and **mitigate urban heat island effect**. Their independent and mobile character allows them to be installed in narrow, pedestrian streets and old town areas with difficult access to water points and with little space for conventional green infrastructures. It also contributes to **enhance attractiveness of the cities** and thus to improve the well-being of citizens.
EXTERNAL LINKS	• Vertical mobile garden (URBAN GreenUP project)

3.6.5 Green shading structures

- Authors: **CARTIF**
- Knowledge Repository link: **https://netzerocities.app/resource-1198**

Green shading structures
They are mainly **shade structures** with a total or partial **vegetated surface**.

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Green shading structures


Shelters in Valladolid (Spain), URBAN GreenUP project

There are different types of shading structure, depending on the structure design and the type of vegetation used, e.g. structure could be **textile or wood**; **vegetation** could be climbing and hanging plants; and installation could be fixed to the **façades** or done by posts.


Parklets in Izmir (Turkey), URBAN GreenUP project (https://www.urbangreenup.eu/news--events/news/new-green-areas-to-enjoy-in-izmir.kl)

Shading structures can be **located** in narrow streets or parks, or installed in areas that need shaded spaces, such as squares or transport stops. They should be projected in compliance with safety conditions (access to fire brigade, cleaning services, etc.).

CO-BENEFITS

Some of the benefits of shading structures are:

- They increase of the amount of vegetation in urban areas, consequently **reducing the temperatures** by up to 5ºC
- They can act as **pollutant filter**, capable of trapping or processing over 150kg of NOx and carbon monoxide
- They can **attenuate noise** up to 40dB
- They can **increase commercial activity** by increasing pedestrian activity
- They increase in the amount of **green spaces** per inhabitant without occupying horizontal space
- They affect the revaluation of the property
- They can be used for aesthetic reasons

Some indirect co-benefits are:

- Increase employment rate and jobs

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Green shading structures	
	• Increase technological readiness • Improve land use management • Improve air quality • Reduce hot spots/urban heat islands in the city • Enhance attractiveness of the cities • Species and pollinator increase • Increase ecological connectivity • Green awareness
EXTERNAL LINKS	• Green Shady structures (URBAN GreenUP project) • Green Covering shelters (URBAN GreenUP project)
EXAMPLES	• Parklets in Izmir (Turkey), URBAN GreenUP project • Leafskin, Green Shady Structure (OPPLA) • Green shades (sombras vegetales) - Singular Green

Green shading structures	
PRE-CONDITIONS & ENABLING CONDITIONS	***Climate and Geography:*** Green roofs serve several functions related to urban biodiversity (Mann, 2002b). They act as stepping stones between nature reserves, such as parks on the edges of cities, and uncolonized habitats in the middle of the city. They provide a return area for plants and animals that previously inhabited an area that has undergone disturbance and development. They also can serve as permanent substitute habitats for plant and invertebrate communities. Plants should be chosen in such a way that they are not invasive, are nutritious for pollinators and do not generate allergies, nor are they sensitive to pests. They should also favour the reduction of temperature and increase of environmental humidity to reduce the heat island effect. ***Urban Form and layout:*** There are different types of shading structure, depending on the possible location within the urban area. Solves the need to provide shade in places where is not possible to plant trees or Green Infrastructures that require more space. These structures can be fixed to the façades or by posts fixed to the sidewalk. Different variants existing: Arbour, Pergola, Trellis or Green Shady Structures. Technical aspects/infrastructure: Green Shady Structures are composed of pieces of stretched textile structure on which an inert substrate is installed. This inert substrate is covered with seeds, which germinate and grow on the textile structure. This NBS can be fixed to the façades of the buildings on the street or by posts fixed to the sidewalk. ***Policy and regulatory/legal framework & Project governance and implementation modalities:*** The installation of green roofs can earn building LEED points, and if the building reaches LEED certification, can receive tax credits between €6,5 – 57/m². All ordinances regarding access to emergency services, municipal services, safety distances for vehicles and pavements, etc., must be taken into account when installing the system. ***Funding and financing:*** The green shady structures get the recovery of the investment between the 10 and the 20 years. ***Economic and social context:*** A German study demonstrated that green roof vegetation can significantly reduce diesel engine air pollution (Liesecke and Borgwardt, 1997) Yok Tan and Sia (2005) found a 37% and 21% reduction of sulfur dioxide and nitrous acid respectively directly above newly installed green roof. Others have estimated that green roofs

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Green shading structures	
	can remove dust particulates per year per square meter of grass roof (Peck and Kuhn, 2001) Hard surfaces in urban areas are more likely to reflect sound, whereas green roofs absorb sound waves because of the nature of the substrate and vegetation. At the airport in Frankfurt, Germany, a 10 cm deep green roof reduced noise levels by 5 dB (Dunnett and Kigsbury, 2004) Other research shows that 12 cm of green roof substrate alone can diminish noise by 40dB (Peck and Kuhn, 2001)
CONSTRAINTS/ BARRIERS for implementation	Firefighting regulations: The selected solution must allow the circulation of a firefighting truck and unfold the ladder at any point of the street. The solution with climbing plants doesn't allow any of those conditions at the narrow streets of the city centre. The adopted solution allows the circulation of the fire truck and also has an emergency mechanism that hooks off the shade very fast so the ladder can be unfolded at any point of the street. Regulations for the pedestrian and vehicles traffic and minimum separation Private property, the owners exposed many doubts about it and to get the permission was very difficult
INSTRUMENTS/ Processes for implementation	• Capacity building for city officials to understand urban metabolisms and circular solution opportunities: https://netzerocities.app/resource-1568 • Capacity building and training: https://netzerocities.app/resource-1578 • Engagement, co-creation and co-design of NBS and Green Infrastructure plans and interventions: https://netzerocities.app/resource-1608 • Loans for Energy Efficiency (EE): https://netzerocities.app/resource-1648 • Integrated land use and urban planning with energy and climate: https://netzerocities.app/resource-1678 • Integrated climate plans for cities (i.e.: SECAPs): https://netzerocities.app/resource-1698 • City water resilience assessment: https://netzerocities.app/resource-1738 • Public procurement for innovative NBS and Green Infrastructure interventions: https://netzerocities.app/resource-588 • NBS and Green Infrastructure regulation and ordinances: https://netzerocities.app/resource-1813 • NBS and Green Infrastructure plans and strategy design and governance: https://netzerocities.app/resource-1823 • NBS and Green Infrastructure Mapping: https://netzerocities.app/resource-1863
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	***Technical and social difficulties*** to allocate the supports on the floor. Location of pipes, cables, etc., and to shut down the service to the citizens would be a big disorder to the neighbours. Also, the works to open and close the pavements have a very negative impact on the shops and citizens. The final solution allows a fast installation. ***Operational and Maintenance Considerations:*** • Maintenance requires a crane for work at heights • Regular maintenance of the Green Covering Shelter is required, consisting on a monthly visit to the NBS, in which the following tasks are performed: • Visual inspection of the vegetation status. • Visual control of irrigation operation. • Maintenance and start-up of the irrigation system: Filter cleaning, pH and conductivity control. • Visual control of pests. • Supply of hydroponics consumables (fertilization, acid, spare parts, etc.) In addition to that monthly visit, there will be: • Preventive phytosanitary treatments twice a year (1 in spring and 1 in summer) • Pruning and growth control twice a year.

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Green shading structures	
	• System of telematics control of the irrigation in a maximum term of 3 natural day
IMPACTS (Indicators & DNSH)	In summer days with a 16 cm thick substrate the temperature can be reduced up to 15ºC. In winter days with the same substrate the temperature under the substrate can be maintained up to 13ºC above the outside temperature. (G. Minke 2005) A green roof with 20 cm of substrate and expanded clay, is able to retain 90l/m2 of water (Dürr 1995).
	The challenges that afford this NBS are: ***Climate change mitigation & adaptation:*** Green roofs reduce the heat island effect. They increase the thermal insulation in the building and therefore reduce the use of energy in air conditioning and heating. ***Air quality*** The plants are able to absorb polluting substances ***Green space management*** Green roofs increase the green areas and create new little ecosystems ***Potential of economic opportunities and green jobs:*** This NBS creates new value chains including implementation and maintenance jobs. ***Public Health and Well-being:*** This NBS is able to reduce noise thanks to the absorption of the substrate and the reflection of its leaves ***Urban regeneration*** The green roofs increase the economic value of the building. ***Water management*** The retention layer reduces urban run-off water
Additional information from CASE STUDIES	***Green Shady Structures, URBAN GreenUP*** In the city of Valladolid, each one of the pieces is triangular with an approximate length of 4m on each side.

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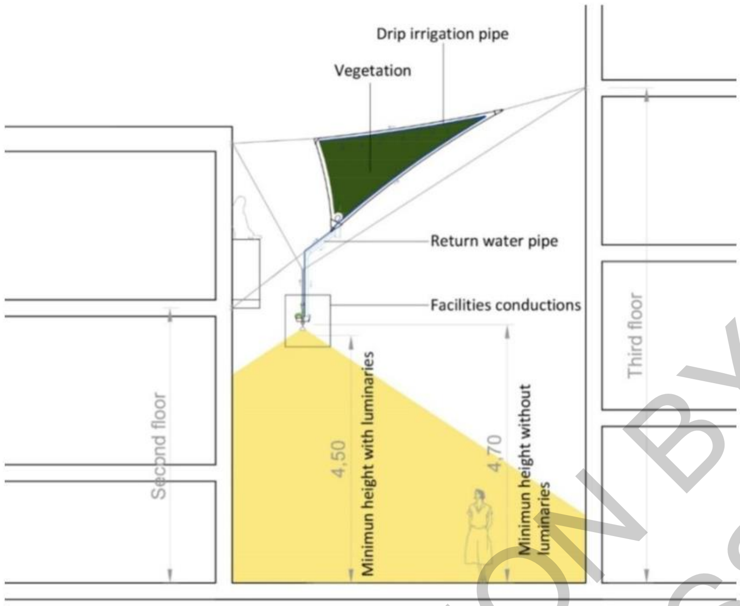
Green shading structures	
	 Figure 3.44: General section - Green Shady Structures (Source: SingularGreen).  Canopies where you can see the anchoring system to the facade, as well as the drainage pipe of the canopy that goes to a canalisation that was also used for planting. In addition, an efficient lighting system with sensors has been installed that is activated by the approach of people and attenuates the light after a period of time with no pedestrians. (source: URBAN GreenUP)

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Green shading structures	
	 Press kiosk converted into an irrigation station, where it houses the connection to the water network, and a hydroponics / fertigation system with fertiliser, EC and pH monitoring controlled by remote control and piping that carries irrigation to the awnings/sails and collects excess water for reuse. (source: URBAN GreenUP)

Santa María Street	unit	quantity	Price (€)	Amount (€)
Vegetable covering Leaf-skin	m^2	146	403,61	58.927,06
Stretched textile structures	unit	21	2587,00	54.327,00
Supply and installation of irrigation centralization inside the kiosk	unit	1	9601,96	9601,96
Aluminum truss	m	201	190,80	38.350,80
Water connexion	unit	1	3000	3.000
Sanitation water connection	unit	1	3000	3.000
Adequacy of the kiosk	unit	1	3000	3.000
Total budget of material execution (€)				170.206,82
Tender budget with VAT (€)				245.080,8

Arbour, Pergola and Trellis:
https://nbs-explorer.nature4cities-platform.eu/

3.6.6 Floating gardens

- Authors: **CARTIF**
- Knowledge Repository link: **https://netzerocities.app/resource-1218**

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the “orange” fields of this solution, and then it has been afterwards reviewed by JRC and completed the “pink” fields, and the Knowledge Repository content has been updated with JRC’s input. So, here only the “orange” fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

Floating gardens
Floating gardens are self-contained ecological units, which can provide habitats for various **aquatic and terrestrial species**. Floating gardens can take many forms including **pontoons, floating platforms and barges**.

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<table>
<tr><th colspan="2">Floating gardens</th></tr>
<tr><td colspan="2">
Floating islands. Source: URBAN GreenUP (H2020 Project GA No 730426) and Liverpool City Council

Some are constructed from a plant material floating sub-layer such as water hyacinths and then have planted flora, fauna or food products growing on top. Others use materials with a natural buoyancy, i.e. plastics or woods, as the sub-layer. Floating gardens provide habitats for varied marine/terrestrial species, opportunities for urban agriculture and climate change mitigation. They can also act as connective features linking habitats across urban boundaries (dependent on size/location and species mix).</td></tr>
<tr><td>CO-BENEFITS</td><td>This NBS contributes to enhance greater biodiversity, providing an increase in ecological connectivity. In addition, this NBS can provide social cohesion and inclusion, as it can be used to re-naturalise humanised watercourses, such as channels and harbour areas, without affecting the functionality of these areas.</td></tr>
<tr><td>EXTERNAL LINKS</td><td>• Floating gardens (URBAN GreenUP project)</td></tr>
</table>

3.6.7 Green filter area

- Authors: **CARTIF**
- Knowledge Repository link: **https://netzerocities.app/resource-1228**

Green filter area
Green filter areas are land application system, constructed to provide a buffer or **pollution filter** between industrial operations, roads, public spaces or walkways. Different typologies of vegetation have different performances and can be combined with solid barriers.

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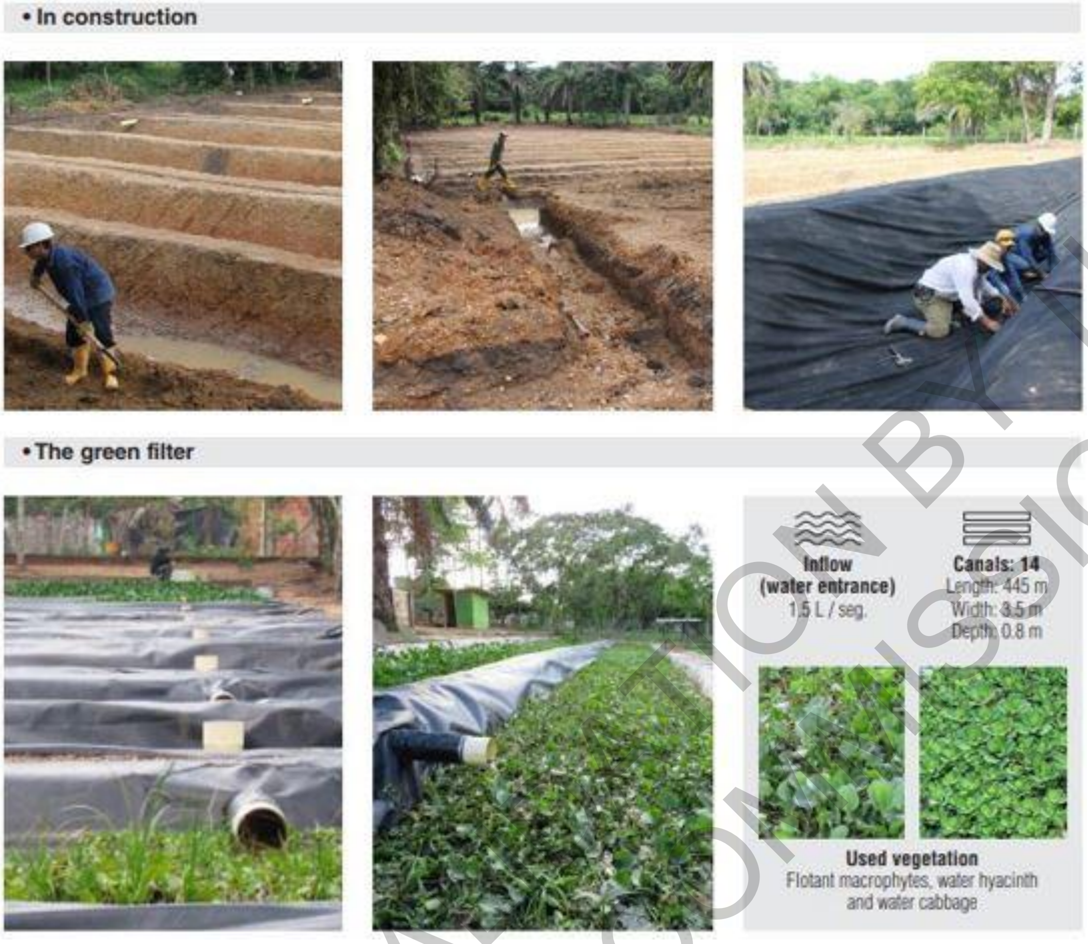
Green filter area



Green Filter area in Colombia

A specific application of green filter is used for **treating water (wastewater)**. It consists of a plot area, sized according to the influent to be treated, which has forests installed and is irrigated with wastewater. The residual water partially evaporates and the rest is taken up by the roots of trees and filtered through the soil. Before application to the **soil**, it is desirable to introduce a primary treatment system, to remove coarse solids, sand, grease and solids. However, these systems provide more than just simple purification, because while treating the water, we are also producing biomass with high economic value.

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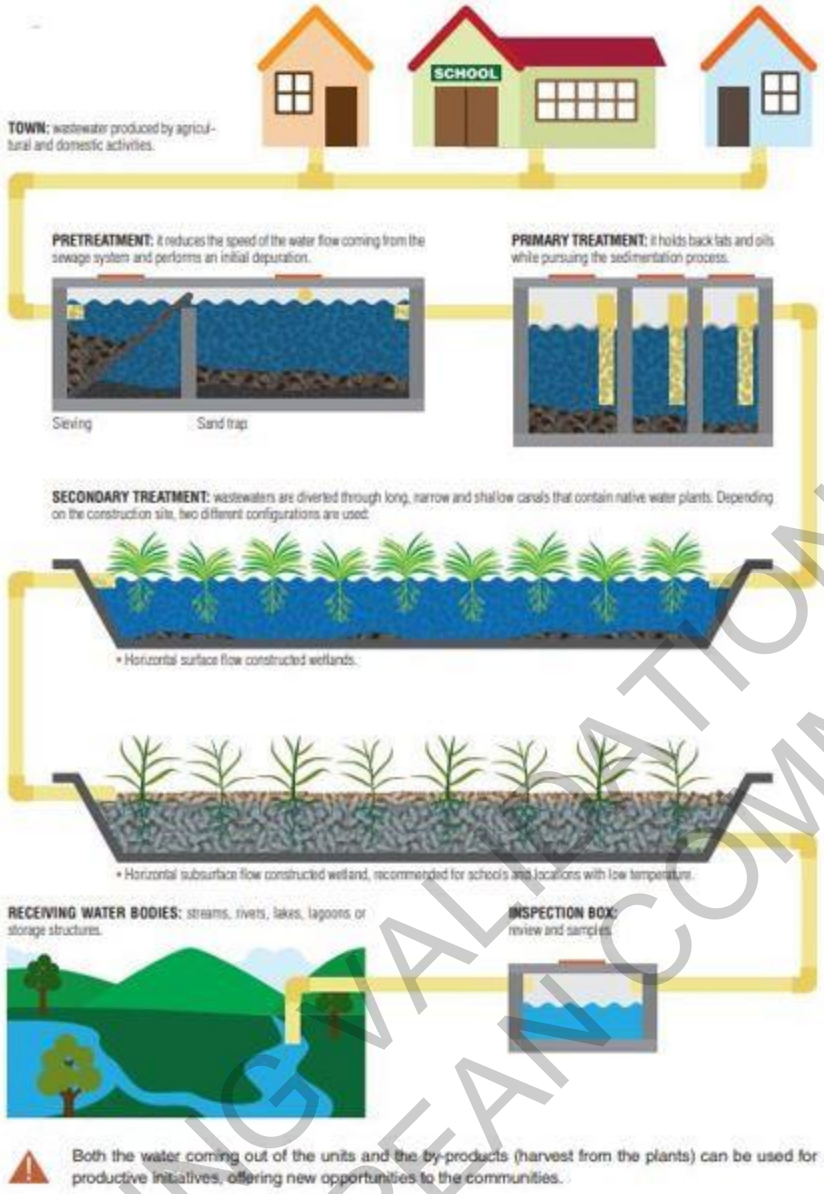
Green filter area



Land Application Systems are considered a reliable, robust and low maintenance technology. This, together with the moderate cost of implementation, makes Land Application Systems a very competitive technology for treating wastewater from small towns or isolated areas.

CO-BENEFITS	The production of **biomass**, either high quality (cycles greater than 10 years) or intensively (cutting cycles 2 to 3 years), generates a by-product of commercial value that reduces the final running and maintenance costs. Additionally, the added value generated by the **capture of CO2 in the biomass growth processes** may constitute an input to be considered in the case of larger installations. Recharging with the treated surplus is another big advantage, which can enable reuse in periods of great demand. Finally, the environmental impact caused by this type of treatment is minimal, and in some cases positive, as it generates a forest ecosystem of great natural and scenic value. Therefore, the main co-benefits of this solutions are: reduce risk to natural and climate hazards, **carbon sequestration**, boost local business, increase technological readiness, raised awareness/behavioural change, **better water**

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Green filter area	
	quality and better water management, **improve air quality**, **reduce hotspots and urban Heat Island Effect**, **species increase** and reduce ecological footprint.
KEYWORDS	This solution is very much related with other circular economy solutions, such as grey water treatment or rain water management.
EXTERNAL LINKS	• Green Filter area (URBAN GreenUP project)
EXAMPLES	• Green Filter area in Colombia

Green filter area	
PRE-CONDITIONS & ENABLING CONDITIONS	***Climate and Geography:*** This NBS is useful as a pre-treatment for returning water from sewage treatment plants back to the natural watercourse or as a wastewater treatment plant for small municipalities. Therefore, it can be adapted to any climate and geography. The residual water partially evaporates and the rest is taken up by the roots of trees and filtered through the soil. ***Urban Form and layout:*** Green filter is a land application system for treating water (wastewater). It consists of a plot area, sized according to the influent to be treated, which has gardens and urban forests installed and is irrigated with wastewater. It has a moderate cost of implementation and has a very competitive technology for treating wastewater from small towns or isolated areas because this circular water system could be implemented at different scales ((micro/neighbourhood or building scale, meso/district scale) contributing to the recovery of water, energy, nutrients, energy, and other valuable resources. ***Technical aspects/infrastructure:*** Before application to the soil, it is desirable to introduce a primary treatment system, to remove coarse solids, sand, grease and solids. However, these systems provide more than just simple purification, because while treating the water, we are also producing biomass with high economic value. ***Policy and regulatory/legal framework:*** Treated water often has a bad odour and sometimes residues that can attract pests. Therefore, all ordinances for the correct circulation, treatment and use must be complied with. Above all, environmental damage must be avoided. ***Funding and financing, Economic and social context, Project governance and implementation modalities:*** The Green Filter gets the recovery of the investment between the 10 and the 20 years. As an NBS, expenditure can be charged to the municipality's Green Zones budget, as well as subsidies for water treatment, among other sources of funding. On a social level it will have a great impact as it promotes ecological awareness, circular economy, as well as the improvement of the environment and the economic revaluation of the area.
CONSTRAINTS/ BARRIERS for implementation	In the case of the URBAN GreenUP project, Connection to the city sewage to conduct water didn't guarantee a constant volume to the sustainable natural park, although this NBS shows certain robustness against fluctuations (in hydraulic load). Also, urban environments make the soils impermeable so rainwater does not infiltrate the soil forming urban runoff which drains into the drainage network causing environmental degradation. Moreover, there is no specific regulations, so political decisions should require. On the other hand, a small seasonal river is near to the implementation so It has restrictive reuse of water and other regulations, overall high visual impact.

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Green filter area	
INSTRUMENTS/ Processes for implementation	• Educational activities on NBS: https://netzerocities.app/resource-1518 • Supporting municipalities to monitor resource flows in line with impact targets and measurement processes: https://netzerocities.app/resource-1528 • Capacity building and engagement with municipalities to identify and co-create circular solutions and roadmaps: https://netzerocities.app/resource-1548 • Capacity building for city officials to understand urban metabolisms and circular solution opportunities: https://netzerocities.app/resource-1568 • Capacity building and training: https://netzerocities.app/resource-1578 • Educational/ Capacity building barriers identification: https://netzerocities.app/resource-1588 • Engagement, co-creation and co-design of NBS and Green Infrastructure plans and interventions: https://netzerocities.app/resource-1608 • City coaching in NBS: https://netzerocities.app/resource-1618 • Integrated climate plans for cities (i.e.: SECAPs): https://netzerocities.app/resource-1698 • City water resilience assessment: https://netzerocities.app/resource-1738 • Public procurement for innovative NBS and Green Infrastructure interventions: https://netzerocities.app/resource-588 • NBS and Green Infrastructure regulation and ordinances: https://netzerocities.app/resource-1813 • NBS and Green Infrastructure plans and strategy design and governance: https://netzerocities.app/resource-1823 • NBS and Green Infrastructure Mapping: https://netzerocities.app/resource-1863
IMPACTS (DNSH)	***Climate mitigation & Adaptation*** Trees and plants of waste water plant are sequestering carbon and contributing to reduce the effects of climate change and through increasing the urban vegetated urban area also may help to reduce the heat island effect, especially when trees are planted. ***Water Management*** The green filter is designed to treat wastewater before its discharge into the environment (soil). It the latest stage of a treatment train, therefore the water quality is expected to meet the regulations related to wastewater treatment/ reuse. The expected removal rates of the green filter are similar to the ones reported for other natural technologies such as constructed wetlands (90-95% for suspended solids; 85-90% for BOD5; 80-90% for COD; 20-30 N_{total}; 20-30 P_{total} (Ortega, Ferrer, Salas, Aragón, & Real, 2010)). ***Green Space Management*** the Green Filter means the creation of a green area but some limitations to access to citizens must be established in order to avoid the contact with the pathogens in the wastewaters. ***Air Quality:*** Tress existing in green filters contributes to absorb polluting substances and improve air quality. Research results revealed that parks with various types of vegetation played an important role in ameliorating air quality in urban areas through the reduction of suspended particles (TSP), sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) (Yin et al., 2011). Researchers have been conducted in order to assess and quantify the carbon storage and sequestration by urban trees (Davies et al., 2011). Carbon sequestration by trees can also be estimated in monetary values (Baró et al., 2014) ***Urban Regeneration***

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This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

Green filter area

By creating new urban green spaces, Green Filters may contribute some aesthetic benefit to the urban landscape and if they are designed properly, they may help to increase the economic value of the area.
According to several studies, houses with a view of green are 1-15% more valuable. Offices with green spaces nearby can be 10% more valuable (de Roo, 2011).

Potential of economic opportunities and green jobs
The Green Filter, such as any other wastewater treatment plant, demands operation & maintenance tasks which require skilled personnel (supervisor and operators). Depending on the size and complexity of the installation the periodicity of those tasks will vary.
Around 160 h/year of operator are required for O&M for a natural wastewater treatment plant (Ortega, Ferrer, Salas, Aragón, & Real, 2010). Therefore, the installation of this NBS will partially contribute to the generation of green jobs.

Additional information from CASE STUDIES

Water provision
Water from the last pond of the NTWP (VAc13) will be pumped to the green filter area. The following table shows the specifications of the submersible pump.

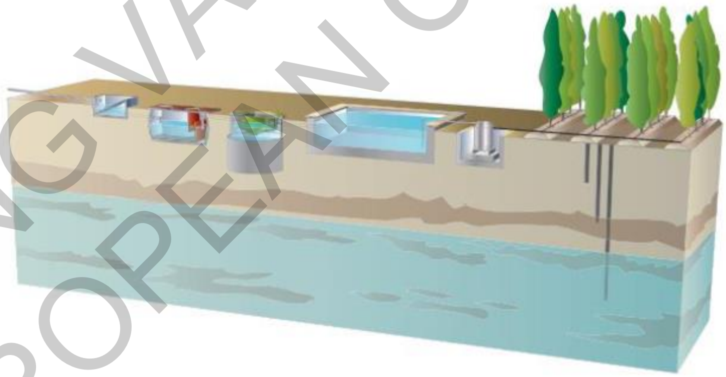
Flange DN	Motor Power (kW)		Rated current (A)	Rated voltage (V)	Speed (rpm)	Flow max (l/s)	Hmax (m)
	P1	P2					
50 DIN	6.08	5.50	10.30	400 3~	2900	6	35

Table 4.16: Technical specifications of the submersible pump

Technical Specifications of the submersible pump

The pumping pattern (and volume of water deviated to the green filter) will depend on the water demand of the vegetation/trees planted in the area.

Irrigation system
Drip irrigation will be implemented in the green filter area to avoid the production of aerosol, and, consequently, the reduction of the risk of contact with the citizens.



Typical flow-sheet of a Green Filter or Land application system (Source: Instituto IMDEA)

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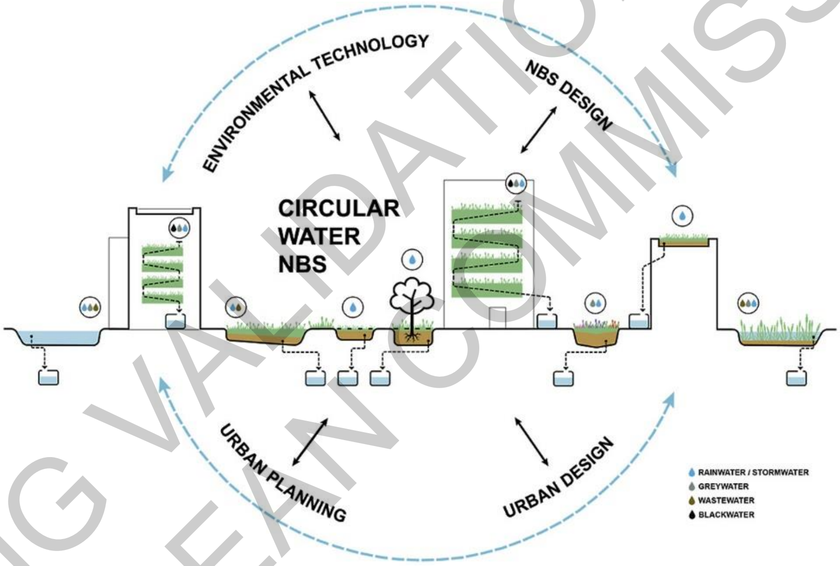
Green filter area

Green Filter/ planting trees	unit	quantity	Price (€)	Amount (€)
Installation works				
Water supply and drainage	m	n/a	45-55 €	
Irrigation system - Irrigation canalization - Drop irrigation system - Sprinkler irrigat. system	 m m2 m2	 n/a	 35-40 € 2,5 € 15 €	
Plantation works				
Ground preparation	m2	n/a	0,85	
Tree planting	unit	n/a	13-30-45 €	
Tree/plant supply - Costs depending on the size (small, medium, tall) (transport not included)				
Conifer tree	unit	n/a	30-60-90 €	
Leafy tree	unit	n/a	25-60-105 €	
Total budget of material execution (€)				**13,223.14**
Tender budget with VAT (€)				**16,000.00**

Table 4.17: Green filter area budget
(Source: Base Paisajismo www.basepaisajismo.com)

Green filter area budget. Source: Base Paisajismo

Other sources:



Scheme of Circular water NBS

Alexandra Tsatsou, Niki Frantzeskaki, Simos Malamis,
Nature-based solutions for circular urban water systems: A scoping literature review and a proposal for urban design and planning,
Journal of Cleaner Production,
2023,
136325,
ISSN 0959-6526,
https://doi.org/10.1016/j.jclepro.2023.136325.

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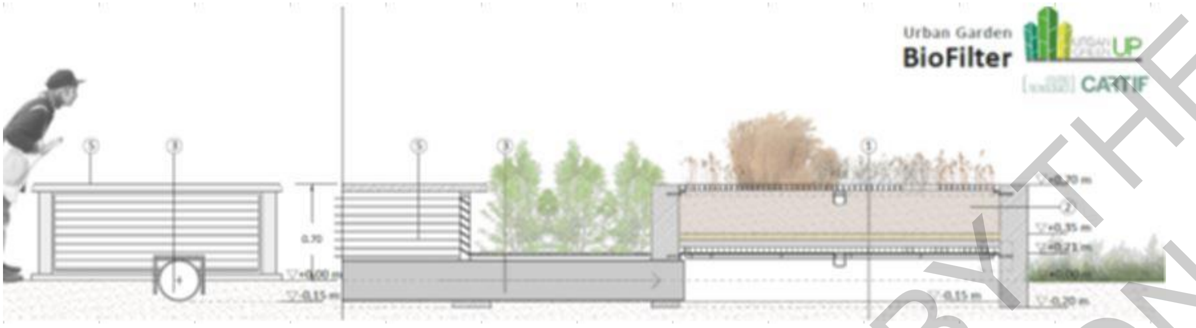
3.6.8 Urban garden bio-filter

- Authors: **CARTIF**
- Knowledge Repository link: **https://netzerocities.app/resource-1238**

This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

Urban garden bio-filter	
Urban Garden Biofilter is an air filter framed in an urban garden to **reduce the emissions** of underground **car parks** or other stationary sources of pollutant compounds in urban environments. This NBS can be adapted to existing car parks or tunnels, or included in the design of new infrastructures.	



Urban garden bio-filter, URBAN GreenUP project

It is composed of three main elements:

- the extractor system to extract the polluted air from underground areas/ car parks;
- the plenum section to distribute the air under the Biofilter and
- the Biofilter itself to clean the air and metabolize pollutants.

The Urban Garden Biofilter **captures most of NOX and PM** (>90%) from indoor air (pollutants concentration 0.5-1 ppm).

CO-BENEFITS	Urban garden biofilters for air pollution have a high impact on health due to the **improved air quality**. Biofilters will also promote a **greater biodiversity**. They have a direct impact on the **increase in species and pollinators**, support the increase of ecological connectivity and contributes to more collaboration and **green awareness**. In addition, biofilters will reduce the risk of epidemics and the ecological footprint.
EXTERNAL LINKS	• Urban Garden Bio-Filter (URBAN GreenUP project) • Evaluating the Impact of Nature-based Solutions: A Handbook for Practitioners *[Page 225]*

Urban garden bio-filter	
PRE-CONDITIONS & ENABLING CONDITIONS	URBAN Garden Biofilter is proposed to extract a controlled and small flow of air continuously and pass it through the soil of the garden in which the biofilter is integrated. The biofilter is composed of a series of layers that sequentially capture the main pollutants present in the combustion gases that reduce urban air quality, nitrogen oxides and particulate matter. The top layer of the biofilter is a high porosity substrate that is maintained at low humidity levels and in which a series of native species with low water requirements are planted and no large roots as these could damage the filter. ***Climate and Geography:*** The urban garden bio-filter can be placed in any smoke extraction, especially from vehicles, heaters and other infrastructures as filter framed in an urban garden of pollutants in urban environments. The biofilter is divided in three parts, the most sensitive part to Climate and Geography are layers for support, pollutants absorption and protection and the vegetation which covers these layers. The main reason is the outdoor location of this Nature Based Solution (NBS), it is designed to withstand a certain amount of water, so that it does not damage the smoke extraction system as excessive daily irrigation or high rainfall over a long period of time can flood the system. Therefore, irrigation of the selected species will be shallow and weekly with native species adapted to the requirements imposed.

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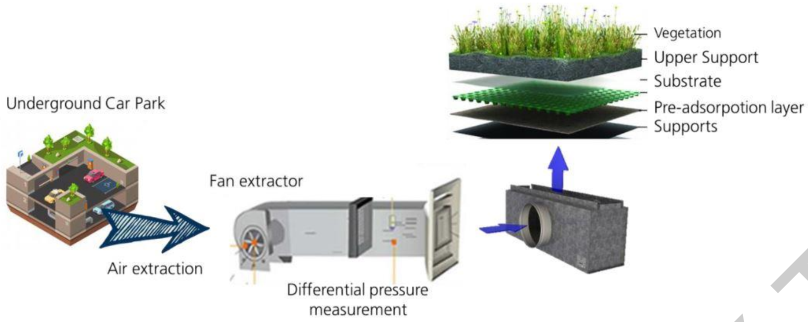
<table>
<tr><th colspan="2">Urban garden bio-filter</th></tr>
<tr><td></td><td>

Urban Garden Bio-filter front view (Source: CARTIF)

Urban Form and layout & Technical aspects/infrastructure:
Inside tunnels and car parks, combustion gases are confined and accumulate. These are eventually emitted to the outside world through the entrances and exits of the car parks as well as through the extraction towers.
The system is going to be installed next to one of the indoor air exit areas of the underground car park and must be dimensioned proportionally to the amount of flow to be filtered, as well as to hide within the structure of all the components

Policy and regulatory/legal framework:
The construction of this NBS must meet planning and safety criteria.
Funding and financing & Economic and social context:
This action could be led from different municipality areas (at least urbanism, environment and heritage).
Also, by private funds that have car park property, construction companies

Project governance and implementation modalities:
It would be interesting if the municipalities made it compulsory for all public car parks and private car parks with a certain volume of vehicles and plants to install this NBS. In addition to boiler outlets in public centres, ventilation outlets in tunnels and underground railways.</td></tr>
<tr><td>CONSTRAINTS/ BARRIERS for implementation</td><td>The main difficult aspect is found in the design and project phase for the implementation of this NBS. Problems with the exact location of the smoke outlet, dimensions, it would have been easier to build the URBAN BioFilter in parallel to the construction of the car park.
Impact assessment can be carried out by using one or several of the indicators depending on the budget or monitoring tool available.
Monitoring locations should be done by experts for the first studies because this is an innovative solution.</td></tr>
<tr><td>INSTRUMENTS/ Processes for implementation</td><td>• Educational Activities on NBS: https://netzerocities.app/resource-1518
• Capacity building for city officials to understand urban metabolisms and circular solution opportunities https://netzerocities.app/resource-1568
• Engagement, co-creation and co-design of NBS and Green Infrastructure plans and interventions https://netzerocities.app/resource-1608
• Integrated land use and urban planning with energy and climate https://netzerocities.app/resource-1678
• Integrated climate plans for cities (i.e.: SECAPs) https://netzerocities.app/resource-1698
• Decarbonisation Plans for Industry https://netzerocities.app/resource-1718
• Governance EU Climate Neutrality Framework https://netzerocities.app/resource-1728
• Public procurement for innovative NBS and Green Infrastructure interventions https://netzerocities.app/resource-588
• NBS and Green Infrastructure regulation and ordinances https://netzerocities.app/resource-1813</td></tr>
</table>

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Urban garden bio-filter	
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	***Climate and Geography:*** There are some operational and maintenance considerations (this action is usually done by the gardening team in charge of the area): • Vegetation and soil manage. • Visual supervision monthly. • Soil aeration bi-annual. • Weekly watering in summer time (out of this period only in case if dry season). Extraction installation (Operation to be carried out by the extraction system installer during at least the two first years.) • Annual maintenance (according to the installation manual) • Differential pressure supervision constantly.
IMPACTS (Indicators & DNSH)	***AIR QUALITY Indicators:*** ***Annual mean levels of fine pm2.5 particles*** • <u>KPI definition:</u> Annual mean levels of fine (PM2.5) particulate matter in cities concentration recorded ug/m3. Unit: PM2.5 µg/m3 • <u>Measured method</u>: A portable photometric sampler designed to measure ambient PM2.5 and PM10 concentrations. This KPI requires a portable monitor because the quite big measurement points. ***Annual mean levels of fine pm10 particles*** • <u>KPI definition:</u> Annual mean levels of fine (PM10) particulate matter in cities concentration recorded ug/m3. Unit: PM10 µg/m3 • <u>Measured method</u>: A portable photometric sampler designed to measure ambient PM2.5 and PM10 concentrations. This KPI requires a portable monitor because the quite big measurement points. ***Air quality monetary values*** • <u>KPI definition:</u> Value of air pollution reduction. Unit: €/$... • <u>Measured method</u>: City official data plus city platforms and surveys by questionnaires and small- medium enterprise accounts
	DNSH: ***Climate change adaptation*** This NBS helps to reduce particulate pollutants in the air. ***Sustainable use and protection of water and marine resources*** As the number of particles in the air is reduced, they will also be reduced in the rainwater that carries particles from the air. ***Pollution prevention and control*** This NBS helps to reduce particulate pollutants in the air. ***The protection and restoration of biodiversity and ecosystems*** Plants have several layers of substrate and plants that fix and keep the substrate aerated by exploring it with their roots, allowing microorganisms to live in the soil and, as they are native plants, they will also help pollinators to feed, helping urban biodiversity.
Additional information from CASE STUDIES	URBAN GreenUP adsorbent material (thickness 5 cm). This material must be able to adsorb at least 2.72-10-3 mg NO/min/m2 (result based on laboratory test using a flow rate of 3L/min of air with 1 ppm NO under normal conditions, see graph below).

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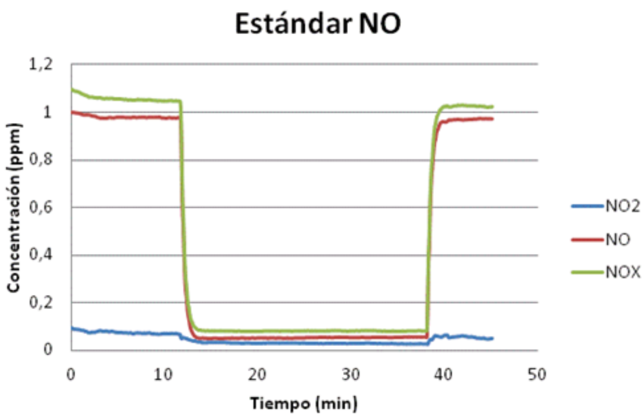
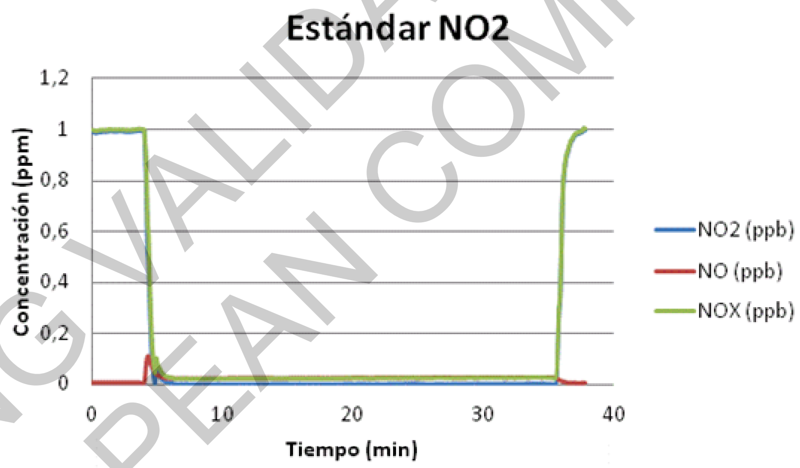
Urban garden bio-filter



Standard concentrations. Source: URBAN GreenUP

URBAN GreenUP fibrous material (thickness 5 cm when spreading). Material of natural origin consisting of non-braided fibres that is a by-product of processes that take place within 250 km. A suitable material would be the by-product of the wool washing and combing industry.
URBAN GreenUP vegetal substrate (thickness 35 cm). This material must be able to adsorb at least 4.16-10-3 mg NO2/min/m2 (result based on laboratory test using a flow rate of 3L/min of air with 1 ppm NO2 under normal conditions (see graph below).



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Urban garden bio-filter

Urban garden biofilter	unit	quantity	Price (€)	Amount (€)
Extraction system				
Fan extractor: 0,25kW/3.500m3/h. Eg. THGT/4-450-6/22-0,25KW-F300-3-230/400V-50HZ-50HZ-IE2 Pipes, piping systems, fittings and other accessories including electrical panel with protections and elements according to current legislation. Labour Other	unit n/d n/d	n/d	5.000 €	5.000 €
Electrical power supply				
Solar panel Accessories Labour Other	unit n/d n/d	n/d	5.000 €	5.000 €
Filter holder				
Preparatory operations. Surrounding wall*. Plenum chamber Filter's support (2 x Tramex layer, stainless steel mesh 1mm and sheep wool blanket) Labour Other*			17.000 €	17.000 €
Engineering project				
Engineering project			3.000 €	3.000 €
Total budget of material execution (€)				**24.793,00 €**
Tender budget with VAT (€)				**30.000,00 €**

3.6.9 Green resting areas, parks and urban forests, parklets

- Authors: **South Pole**
- Knowledge Repository link: https://netzerocities.app/resource-1258

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the “orange” fields of this solution, and then it has been afterwards reviewed by JRC and completed the “pink” fields, and the Knowledge Repository content has been updated with JRC’s input. So, here only the “orange” fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

Green resting areas, parks and urban forests, parklets
Cities are at the forefront of resilience challenges such as urbanisation, change and loss of biodiversity, poverty, environmental degradation and socioeconomic inequality. Incidents of heatwaves, floods and droughts have led to severe economic losses and wellbeing. It is crucial integrate nature-based solution (NBS) into city planning. **Green resting areas and parklets** are NBS that provide an easy solution in creating **green urbanisation**, enhancing biodiversity, creating livelihood opportunities and enhancing the environment. That consists on **small green public spaces** created in the neighbourhood. They provide facilities such as resting, planting and bicycle parking. They act as a **natural air filter** framed in an urban system.

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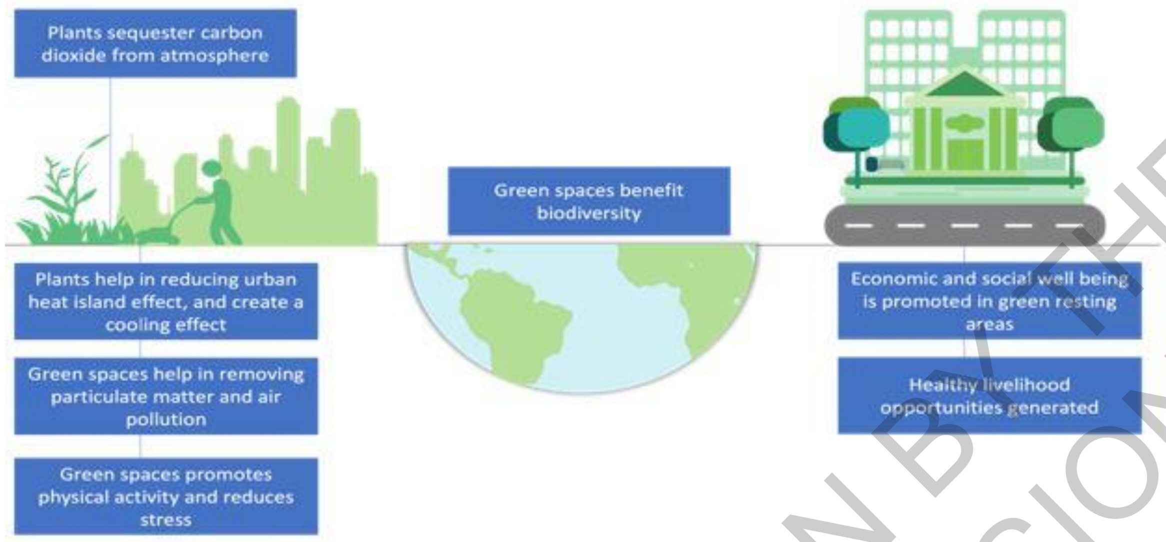
Green resting areas, parks and urban forests, parklets



This NBS can be adapted to existing **infrastructure** settings or included in the design on new infrastructures. The solution will enhance strategically planned network of natural and semi-natural areas and add other environmental features to it while giving additional benefits. The solution will support in reducing GHGs as plants and trees act as **carbon sinks** and help in sequestering harmful gases. It will further help in improving the health, well-being and resilience of urban dwellers, as well as reducing or diminishing heat traps and improving ambient air quality, while providing ancillary benefits for people residing in urban areas.

CO-BENEFITS	
	• **Air quality improvement**: Plants are the greatest source of removing air pollutants, smog and harmful UV rays from the atmosphere. • **Improve human health and enhance citizen participation, connectivity, and community**: These spaces create a green network space and support the busy city life that improves health, prosperity, and happiness of citizens. • **Enhance biodiversity and pollinator increase**: With enhanced green areas, an instant improvement in biodiversity is observed. It contributes to soil moisture content enhancement, improves the nutrient cycle and thereby impacting the surrounding flora and fauna. • **Green mobility**: The spaces offer aesthetically green spaces to move around in the built concrete spaces. • **Increase carbon sequestration**: Green areas increase the absorption of carbon dioxide and increase the supply of oxygen.

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Green resting areas, parks and urban forests, parklets	
	• **Reduce hot spots/urban heat islands in the city**: Trees and plants reduce the impact of urban heat island effect as they create a cooling effect around them. • **Enhance attractiveness of the cities**: The green areas create aesthetically beautiful environment in the cities which further beautifies the city. It creates an interconnected network of green spaces that interest the citizens and harmonizes the negative impacts of urban expansion.
KEYWORDS	This NBS is related with other solutions such as urban carbon sink, cycle and pedestrian green route, cooling trees, and other solutions related to water and green interventions.
EXTERNAL LINKS	• Choosing the right nature-based solutions to meet diverse urban challenges • Compendium of Nature-based and 'grey' solutions to address climate- and water-related problems in European cities (GrowGreen project) • Green Resting Areas (URBAN GreenUP project) • NBS Handbook (Think-Nature project) • Addressing climate change in cities, NBS catalogue • Nature and net zero: Why investing in nature is important (World Economic Forum) • Approaches to financing nature-based solutions in cities (GrowGreen project) • Designing for biodiversity in low carbon and net zero buildings (UK)
EXAMPLES	• Benefits of parklets, UK Case study

3.6.10 Cooling trees

- Authors: **CEREMA**
- Knowledge Repository link: **https://netzerocities.app/resource-1268**

Cooling trees
Cooling trees are appropriate at different **scales**: • the isolated tree: in a park, a street or in a square; • rows of trees along a street: on either side of a street, on one side of a street or in a central row; and • at the scale of a city: forming what is called an urban forest. In terms of mitigation, trees contribute to **carbon sequestration** through photosynthesis, which transforms carbon dioxide into organic matter. This stored carbon is found: • in the **above-ground biomass**: stems, stumps, branches, bark, seeds, foliage or dead wood; • in the **underground biomass**: living or dead roots; and • at the **soil level**: decomposition of litter (dead leaves and plant debris) or root exudates. The **tree stores carbon** as soon as the inflow of carbon resulting from the photosynthesis process is greater than the outflow of carbon (autotrophic respiration of the tree, heterotrophic respiration of decomposers and other micro-organisms in the dead tree and in the litter).

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Cooling trees

Mechanisms involved in cooling: shading (grey flat), evapotranspiration (dotted arrow). On the other hand, the wind resistance of the tree (curved solid arrow) reduces the air speed (hence a cooling effect that can be neutral or even negative at night).

In terms of adaptation, trees provide a **cooling effect**. This **temperature-reducing effect** is due to shading and evapotranspiration, which is the loss of water through evaporation and transpiration that contributes to humidifying the air, and therefore cooling. On the scale of the city and the street, the cooling tree therefore helps to **reduce the urban heat island effect**. At the pedestrian scale, cooling trees improve comfort during the day, but at night, the effect of trees is neutral, or even negative, because of the obstacle that trees can represent in relation to the wind (particularly for a large tree cover).

Cooling tree also have co-benefits, particularly in terms of **biodiversity** and **well-being**. But the pollens of certain trees (e.g. birch, chestnut, olive, cypress) cause certain allergic reactions. A supply of water is also essential for the tree to become an air conditioner.

It should be noted that the impacts in terms of mitigation and adaptation, as well as the co-benefits described above, depends on the choice of species and their spatial organisation.

CO-BENEFITS	In terms of **biodiversity**, cooling tree contribute to a significant increase in the number of **animal and plant species** (e.g. birds, insects, mammals, lichens), which the habitat for shelter, reproduction or food. In terms of **health**, cooling trees contribute globally to **improving air quality**. They eliminate certain gaseous pollutants, which are permanently absorbed via their stomata (ozone and nitrogen oxides), and adsorbed in the fatty elements of the cuticle (PCBs, dioxins and furans). The particles are intercepted at the surface of the leaves, particularly if the leaves are rough, hairy or waxy. This interception is temporary, as these particles can be released back into the atmosphere, be washed away by rain or fall to the ground together with the leaves and twigs. It should also be noted that the positive effects described above can be partly counterbalanced by **negative effects**, inter alia: emissions of volatile organic compounds (isoprene, monoterpene) by certain tree species, reduction of wind speed which can lead to an increase in the concentration of pollutants locally, or emissions of allergenic pollens. Cooling trees also contribute to the **well-being** of the inhabitants. Trees –and more generally, nature– in the city **encourage physical activity**, social interaction and reduce stress. They reduce the risk of developing cardiovascular diseases, obesity and mental disorders such as depression, which are linked to a sedentary lifestyle,

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Cooling trees	
	stress and loneliness. They are also identified as factors of **attractiveness of cities**.
EXTERNAL LINKS	• Chang C, Li M, Chang S. A preliminary study on the cool-island intensity of Taipei city parks. Landscape and Urban Planning 2007; 80:386-95 • Myrup LO, McGinn CE, Flocchini RG, An analysis of microclimate variation in a suburban environment. Boston, MA: Seventh Conference on Applied Climatology, American Meteorological Society 1991; pp. 172-9
EXAMPLES	• The requalification of Garibaldi Street at Lyon (France)

Cooling trees	
PRE-CONDITIONS & ENABLING CONDITIONS	***Climate and geography:*** An assessment of current and future climate should be undertaken to identify appropriate local species, as all trees species will not be appropriate according to the local climate and geography. ***Existing environmental conditions:*** Soil, typologies of landscaped areas, location, detailed diagnosis of the existing tree heritage (location, species, ages, health and management) expected ecosystem services shall be analysed and discussed before designing green areas. The project shall then be designed according to the above parameters. ***Connexion with blue and green network:*** Whatever their scale, green urban areas shall be designed holistically considering the continuity of green and blue corridor. The overall objective should be to develop a vegetation strategy for the next 20 or 30 years, sometimes called a "canopy plan", which integrated blue and green network. ***Urban form and layout:*** Available urban spaces and urban form (building height, setback between buildings, depth of open ground, etc) will influence the needs and constraints of the project. They shall be carefully analysed to determine the key principles for planting. ***Technical aspects / infrastructure:*** Planting diversification (with the objectives to use more species and varieties) is a key principle to be considered while defining the planting strategy. In addition, tree positioning vis a vis buildings and houses should be analysed considering bioclimatic principles and keeping in mind positioning tree at right pace can result in maximising energy savings. ***Project governance and implementation modalities:*** Services involved in the maintenance and management of green public spaces shall be involved from the beginning of the project to determine the needs and constraints of the projects and the choice of species to be planted. ***Multifunctionality of spaces:*** Trees in urban areas can provide multiple services: rainwater management, creation of "coolness" islands, fixation of pollutants, support of biodiversity, etc. Involvement and participation of key stakeholders shall be integrated.
CONSTRAINTS/ BARRIERS for implementation	***Urban form and layout:*** Urban areas can be hostile for trees and shrubs (pollution, compacted soil, constrained underground space, etc) if appropriate conditions are not anticipated for the right species Long distance with tree nursery to supply species / Transportation conditions

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Cooling trees	
INSTRUMENTS/ Processes for implementation	• Training • Multi-stakeholders participation • Alignment with territorial or regional strategy aiming to strengthen and preserve biodiversity in relation to the blue and green network
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	The negative effects of trees depend on its species. **Constraints are caused by:** allergenic pollens, honeydew production, brittle branches, toxic fruits / leaves, thorns production, roots that damage the pavement. Its adaptation to urban conditions (pollution, drought, injuries, fragility to diseases and pests) depend on its species. **Underground network and tree roots:** The nature of soil and the encumbrance of the subsoil by the network is a constraint that depends on the site and its choice. The choice of trees species and planting should be done as far away as possible from existing network. The available underground space available should contribute to determine the choice of species to be planted. Watering needs must be carefully anticipated and assessed while choosing trees species to not generate higher pressure and conflicts on water resources **Issues/difficulties with management:** watering needs, cutting, tree pit maintenance
IMPACTS (Indicators & DNSH)	***Expected impacts:*** Adaptation to climate change by reducing the urban heat island effect and "local" cooling, improving stormwater management, improving air quality, positive effect on human health (except if allergenic species) and improving carbon storage • Temperature regulation against baseline • Air pollution and GHG emission- pollution removal through dry deportisation, • Reduce evaporative emissions, • Carbon storage and sequestration, • GHG emission reduction on account of energy savings, • Improved citizens health, • Enhanced stormwater management
	DNSH: Wrong positioning can be counterproductive blocking sun light in winters
Additional information from CASE STUDIES	Sesame, a tool for integrating trees into your urban renaturation projects : Sesame is a tool designed by Cerema with the metropolis of Metz which aims at raising awareness on ecosystem services provided by trees and shrubs in urban areas, on strengths and constraints of different species and on the right methods to plant and promote health. It is a help decision-making tool to choose appropriate species to be planted accodring to different urban species and futures uses. Nature4Cities : Nature4Cities is a Horizon 2020 EU-funded Research & Innovation project, creating a comprehensive reference Platform for Nature Based Solutions (NBS), offering technical solutions, methods and tools to empower urban planning decision making. This will help addressing the contemporary environmental, social and economic challenges faced by European Cities

3.6.11 Green corridors for active and cooler mobility

- Authors: **Resilient Cities Network**
- Knowledge Repository link: **https://netzerocities.app/resource-1278**

Green corridors for active and cooler mobility
The natural and built environment that surrounds us largely dictates our behaviours. When it comes to transportation, the domination of the streetscape by car-lanes naturally leads to higher car ownership

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Green corridors for active and cooler mobility

and use. To address this challenge, the development of **well-connected green corridors** can promote a modal shift away from cars and towards sustainable mobility means, whether this is walking, cycling or micromobility.

Instead of concrete/asphalt roads with little to no vegetation, **green corridors** essentially comprise a linear routes, street, pathway infrastructure, which use a series of swales, rain gardens, street trees, and pervious pavement to create a cooler oasis and promote active mobility. In the case of green corridor, routes and pathways can integrate asphalt, stabilising materials, etc. with different impacts in terms of carbon footprint and comfort (including practicability for people in wheelchairs or with walking difficulties).

Source: centralpark.com

Green corridors can go as far as to form a **green network** which can **connect** neighbourhoods, parks and other open spaces. They can design to offer comfort and safety, while offering opportunities for physical exercise and promoting well-being. Green corridors are also key contributors to social equity, considering that they provide equitable access as opposed to car ownership.

In terms of mitigation, green corridors contribute to **GHG emissions reduction** and air quality improvement thanks to the modal shift they encourage.

In terms of adaptation, green corridors can **reduce the heat urban island**, due to a greater presence of vegetation and water. They can reduce the risk of flooding, by reducing run-off water. Lastly, hard surfaces can make use of pervious materials or high albedo materials to further decrease temperature increase. Green Corridors offer significant co-benefits when carefully designed (improving air quality, enhancing biodiversity, better well-being and health).

CO-BENEFITS	In terms of climate resilience, green corridors contribute climate mitigation. They **reduce the GHG emissions**, due to modal shift and the carbon sequestration with vegetation. Green corridor contributes to climate adaptation, by reducing car use which causes heat rejection and aggravates the heat island. In terms of health, they **improve air quality** and **reduce noise pollution**. They can affordable and contribute to **equity in transport**. They offer improved land use thanks to their small land footprint. They reduce road danger and contribute to **overall well-being** through enhancing attractiveness of cities and offering opportunities for healthier lifestyles. Lastly, in terms of **biodiversity**, they can be part of ecological networks thus contribute to urban biodiversity.

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Green corridors for active and cooler mobility	
EXTERNAL LINKS	• Sustainable Urban Mobility Plans (SUMPs) and Cycling: Guide (EC)
EXAMPLES	• Barcelona: green corridor (NATURVATION project)

Green corridors for active and cooler mobility	
PRE-CONDITIONS & ENABLING CONDITIONS	Green corridors essentially comprise a linear route, street, pathway infrastructure, which use a series of street trees, swales, rain gardens, and pervious pavement to create a cooler oasis and promote active and sustainable mobility, whether this is walking, cycling or micro-mobility. Green corridors can vary significantly in terms of length and use of green materials in their design. The selection of the site where to implement a green corridor largely depends on the urban form, layout of the city and availability of land. Nevertheless, in principle they could be implemented in all neighbourhoods of a city, particularly in the areas which have the lowest score in terms of green areas and permeable surfaces. In particular, green corridors promote alternative mobility means which do not make use of the car. In this sense, they are open, public and affordable, are associated with lower emissions and, hence, promoting equity and accessibility for people with reduced mobility. The choice of which nature-based solutions to adopt in designing green corridors largely depends on local climatic and geographic conditions, making these technical specifications inevitably contextual. While green corridors do not necessarily need policy or regulatory framework to be implemented, they usually require funding to be implemented by the public authority.
CONSTRAINTS/ BARRIERS for implementation	***Technical:*** Land availability, existing infrastructure and land-use compatibilities can represent a potential obstacle to implementing green corridors. This is particularly true for those urban contexts where car ownership and car dependence are still very high, due to a not efficient public transport and the lack of alternative mobility means. Moreover, cities might face resistance from citizens, communities and groups, who are (at least initially) against pedestrianization or unwilling to receive restrictions on the use of the car. In this regard, early civic engagement is crucial for the successful implementation of green corridors, as witnessed for instance in the case of Passeig de Saint Joan in Barcelona. ***Socio-economic:*** Green corridors are generally considered to foster equity, as they promote alternative mobility means and create healthier public spaces. However, large green corridors might affect the land value of specific plots and neighbourhoods, leading to uncontrolled or undesired green gentrification. Furthermore, another issue is the maintenance of green corridors, which requires adequate financial resources, and it this is usually done by the municipality or a public authority – either directly or through contracting. Citizens could be directly involved in planting trees and in the maintenance, as already experimented in cities such as Milan and Belfast (projects ForestaMi and 1 Million Trees respectively).
INSTRUMENTS/ Processes for implementation	There are different options to promote and mainstream the implementation of green corridors within cities. On the strategic level, they could be included as potential interventions under the city's Climate Action Plan or Resilience Strategy; on the operative level, the design and specification of green corridors might be integrated into land-use plans and zoning plan (e.g. low emission zones). In particular, the implementation of green corridors should also be reflected in the city's Sustainable Urban Mobility Plan, considering how these could contribute to the re-design and functional re-organization of mobility infrastructure in the city. In any case, an integrated

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Green corridors for active and cooler mobility	
	approach is needed, linking planning, land-use and mobility. For instance, the city of Lisbon implemented a series of green corridors under the Master Development Plan and Biodiversity Action Plan. Other tools such as Green Infrastructure Mapping could be used to identify neighbourhoods where green spaces are lacking or fragmented, and where green corridors could be implemented. Educational activities and monitoring tools could also be important to promote citizens' engagement, raise awareness about co-benefits, and foster acceptability.
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	Although undesired or unexpected, some drawbacks or adverse impact might happen after the implementation. For instance, the implementation of a large green corridor with stringent car traffic limitation might alleviate car congestion in one neighbourhood but could have opposite effects on other roads and districts of the city. Other potential drawbacks are related to conflicting interests and alternative land use. For example, the city of Stuttgart implemented a large, city-wide scale strategy of green corridors, experiencing conflicts in competing interests and trade-offs, with loss of potential tax revenues from constructions and high housing costs.
IMPACTS (Indicators & DNSH)	Green corridors provide several co-benefits, not only from an environmental point of view. In terms of climate resilience, they contribute to both mitigation and adaptation (thanks to the modal shift from car and carbon sequestration though nature-based solutions). They also foster cooler urban environment, mitigating the impact of extreme heat events and the urban heat island effects in neighbourhoods, and enhance biodiversity thanks to their function as ecological connectors. Green corridors also provide benefits for health and well-being, thanks to improved air quality, noise reduction, active lifestyle and street safety (thanks to the limitation in the use of the car). The impact of a green corridor largely depends on its scale, design and green materials used. Once designed, a green corridor becomes part of the urban context and it is difficult to monitor it. A number of indicators could be used to capture the co-benefits achieved. For instance, estimating the carbon reduction potential based on the numbers of trees planted, monitoring improvements in ecological biodiversity, and measuring temperature to assess the localized cooling effect of vegetation, but also use of green corridors and social acceptance/satisfaction.
	Green corridors are consistent with the DNSH principles for environmental objectives, especially for climate change mitigation and adaptation, pollution prevention and control, protection and restoration of biodiversity. Indicative KPIs to be defined in more detail per study area: • KPI1: Area covered by green space • KPI2: Temperature regulation against baseline • KPI3: Increased number of users of corridors (including segments, e.g. age, gender) • KPI4: corridor connectivity index • KPI5: biodiversity increase • KPI6: Air quality (PM10 and 2.5 concentration)
Additional information from CASE STUDIES	In 2020 the city of Barcelona launched the Barcelona Green Infrastructure and Biodiversity Plan 2020, including the development of several urban green corridors to increase ecological and social connectivity within the city. The green corridor of Passeig de Sant Joan is one of the first of these corridors implemented. The city of Stuttgart implemented a green corridors strategy to create a green infrastructure network, mitigate extreme heat events, and improve air quality. One of the main success factors was that the city institutionalized the integration of urban climatic concerns into planning (i.e., cold air regime, ventilation corridors).

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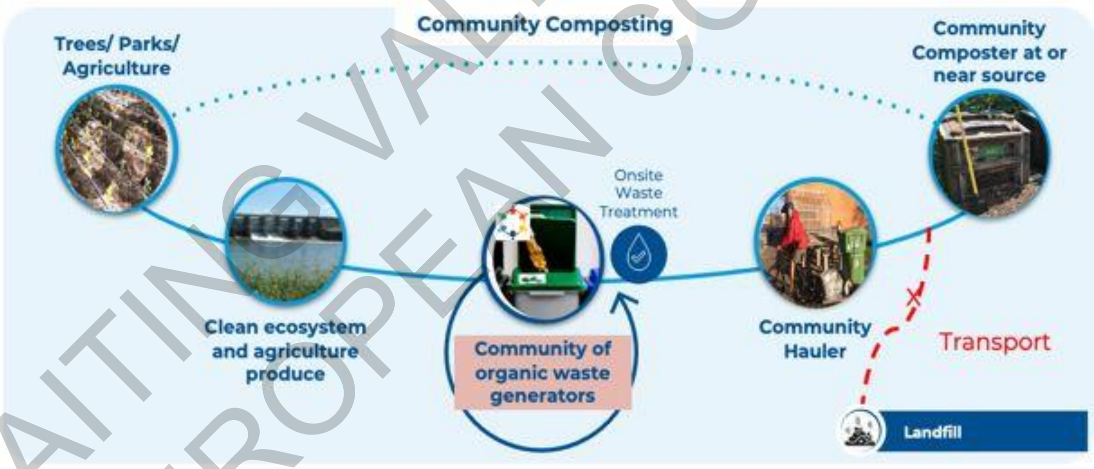
Green corridors for active and cooler mobility	
	The city of Lisbon implemented a series of green corridors under the Master Development Plan and Biodiversity Action Plan. The Main Green Corridor, a 2.3 km long green corridor connecting is considered as the city's largest green infrastructure, crossed by pedestrian/cycle paths.

3.6.12 Community composting

- Authors: **South Pole**
- Knowledge Repository link: **https://netzerocities.app/resource-1298**

<table>
<tr><th colspan="2">Community composting</th></tr>
<tr><td colspan="2">
The EU Waste framework directive (Directive 2018/851/EU) defines a target to recycle 65% of municipal waste by 2035, along with separate biowaste collection or recycling at source by 2023. Composting is a natural method of waste recycling whereby the organic waste, under natural or induced conditions, is converted into organic fertiliser or soil additives.

Community composting is a localised solution for recycling organic solids, wherein different waste generators from one or more urban housing societies, small restaurants and shops collaborate to compost organic waste at a specific site. The output compost is generally used as a fertiliser and for soil amendment in local parks and green spaces within the community area, or sold through municipal buy-back programmes. The main benefit of community composting is that it allows large quantity of organic waste to be managed at- or near-source, avoiding the waste to be diverted to landfills or transported for secondary processing. This in-turn reduces the cost of waste processing for the city, at the same time reducing the resultant carbon emissions from landfills.



Cities may introduce policy and incentive measures to promote community composting by empanelling vendors, providing step-by-step guidelines, introducing compost buy-back programmes, incentivising and recognising communities undertaking community composting, and providing digital platforms for citizen to learn from and collaborate with one another.
</td></tr>
<tr><td>CO-BENEFITS</td><td>

Climate mitigation: reduced carbon emissions (methane reduction) on account of the diverted organic waste from landfills and waste transport emissions;
Climate adaptation: improved soil health, improved air, water and soil quality by replacing chemical fertilisers;
Sharing economy: worker- or people-owned structures can be used;
Decreased costs: lower cost of waste transport and management for municipality;

</td></tr>
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Community composting	
	• **Social capacity building**: increased (green) awareness and knowledge of environmental aspects of waste management; • **Citizen engagement**: the entire process is citizen-led and creates social cohesion; • **Economic opportunities**: green jobs and economic opportunities through the sale of compost; • **Better waste management**: circular economy solution to on-site waste recycling and reuse; • **Sustainable and resilient food system**: compost can be used to promote individual or community kitchen gardens, reducing dependency on external food supply; and • **Greater biodiversity**: compost can also act as a feed for birds.
KEYWORDS	Community composting is directly related to solutions such as urban carbon sink, urban green areas, MSW treatment, MSW prevention, reduction of waste material, cooling trees, and circularity food cities.
EXTERNAL LINKS	• Community Composting: A Practical Guide for Local Management of Biowaste (Zero Waste Europe) • Growing local fertility: A guide to community composting (ILSR)
EXAMPLES	Case Studies: • Case Study community composting in San Francisco (US) • Home and Community composting in Porto (Portugal) • Community composting in the city of Nitra (Interreg Europe)

Community composting	
PRE-CONDITIONS & ENABLING CONDITIONS	Community Composting refers to an initiative undertaken to manage the waste generated by small and large households, by a group of people in a locality (ideally within the society premises or in a nearby shared area). This compost is then used as fertiliser for growing fruits and vegetables within the society or for parks and gardens within the community. The compost can also be sold to for instance garden centers to generate income for the community. Composting also benefits the environment as it reduces the amount of waste that reaches landfill sites ***Climate and Geography:*** Climatic conditions play a vital role in composting – particularly temperature, wind and rainfall, which influence the composting process. Higher temperatures kill pathogens; lower temperatures also slow down the decomposition process. Moisture content also impacts composting, taking more time for making compost in regions with more rainfall or in humid regions. Optimal conditions (in terms of right moisture ~40 to 60%) and temperatures (ideally between 40°C to 65°C) should be maintained for composting ***Urban form and layout:*** Community composting can be done at any designated site within a community. In a housing society, it can even be done on rooftops. The site should be in a covered area so that it is protected by rain. The site should also be properly fenced. The following factors should also be considered. Elevated and away from water: an upland site away from water bodies with a gentle slope of about 2% that drains away. Away from neighbours and with the wind: consider wind direction and downwind position to reduce odour concerns. Away from high water tables: as this increases the potential for groundwater and surface water contamination if the site floods. Protected from storm water runoff: use ramps, compost socks, ditches, and drains can redirect runoff.

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Community composting

Technical aspects/infrastructure:
Community composting can be done in many sites, including schools, colleges and residential societies. The planning of community composting depends on various parameters:

- Site selection: This is one of the most important parameters, and involves avoiding flood plains, consideration of prevailing winds, overall surrounding (land use) and consideration of inhabited areas.
- Access to the community composting site and role of public authorities: It is important to get permission from the authorised users and have initial validation, inspection and monitoring and data tracking done by them.
- Land Ownership: whether the land is public or private.
- Maximum Capacity: Capacity of compost bins depends on the size of the community.
- Materials used for decomposition: This depends on the waste decomposed from household, garden, park or agriculture.
- Operator: This depends on the number of people involved (e.g. manager, composter, technician).
- Community Composting Participation: It is important to spread awareness among the people living in the composting area.
- Compost use: After the decomposition and treatment of waste, the manure can be used in parks, gardens and agriculture as a fertilizer for growing of trees.

Policy and regulatory/legal framework:
Community composting needs to be carefully planned out, in accordance with urban planning principles, and put into practice using a comprehensive approach. The primary goals of EU strategy are effective waste management and selective waste management. Therefore, community composting cannot succeed without the support of an enabling policy environment. Coordination between all stakeholders – including the national and municipal governments, NGOs, financiers, and the private sector – is necessary to ensure that policies are aligned to support composters.

Funding and Financing:
The development of a compost plan at the community level is not a very high investment. Communities can allocate a portion of their waste management funds to the activity. They can also generate revenue from the sale of compost which can be used for its operations. The community will also save on buying compost from outside for maintenance of their parks and gardens and funds can be used for maintenance of the compost plant. In schools and colleges, this can be used as an awareness for students. The system can be created from infrastructure development funds of institutions, and students can contribute to actually maintaining the compost plant. Savings on account of transportation costs to the city can be used as a financing instrument for such projects.

Economic and social context:
Community composting requires support from all in the community for its effective functioning. Communities must be aware of the benefits of composting. In schools and colleges, this can raise awareness for the younger generation on proper management of their waste, positively benefiting the future.

Project Governance and Implementation modalities [1]:
For the successful operation of the system, it is important that it is regularly maintained and monitored by welfare associations, communities, operators or persons-in-charge. Governments and community groups can implement compost sites for yard trimmings and food scraps. Local compost sites provide a low-cost way to collect and compost food scraps. These sites can be managed by non-profits and volunteers. Local and regional governments can provide loans and contracts

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Community composting	
	to non-profits for community composting. It should have strong waste collection and disposal mechanism systems. The implementation steps are: • Identification of suitable land; • Identification of suitable mechanism based on the geographical and climatic conditions of the area; • Development of a proper waste disposal mechanism; • Preparation of a proper Operational Plan; and • Undertaking awareness programmes. [1] Community Composting: A Practical Guide for Local Management of Biowaste (Zero Waste Europe, 2019)
CONSTRAINTS/ BARRIERS for implementation	**Climate and geography**: The climatic conditions of an area will impact the time taken for the decomposition of waste. Composting is a four-phase process characterised by changing temperatures: initial (mesophilic) phase (25–40 °C), thermophilic phase (35–65 °C), cooling (second-mesophilic) phase, and maturation phase. Temperature controls microbial activity. 40–65 °C is ideal for composting. **Technical aspects/infrastructure:** The disadvantages of composting by-products include the cost of site preparation and equipment, the lengthy treatment period, the final use of the compost product, and environmental issues such as odours and dust. Some investment in equipment and site preparation is required or recommended. Composting is a slow process that can take several weeks to complete depending on the technique used. The determination of a suitable market for compost is critical to justify the extra effort in producing compost. Composting is a biological process that, if not properly managed, can result in significant odour generation. Because of the slow release nature of nutrients in compost, higher application rates are required to achieve the same plant response as the original by-product. Higher application rates require more material and more trips across the field than the original by-product. **Economic and social context:** The limited awareness about community composting and its importance to the environment may create an issue among communities. Food scraps can be thrown in the yard waste bin if citizens are aware of three things: The value of composting; How to compost; and What can be composted. Barriers include the notion that composting takes a lot of time in the absence of a formalised household system to collect food scraps, and the low priority given to composting. People who don't compost may also be worried about pests or unpleasant odours. The operation of composting requires full-time involvement of operators to effectively manage the system. **Policy and Regulatory/Legal Framework:** Since governmental support for community composting programmes is frequently insufficient, public encouragement and involvement are crucial. Public knowledge and technical proficiency should be well-established in this regard. National legislation on community composting should serve as the primary guide when creating a decentralised composting framework, especially when selecting pilot sites and reactor systems to reduce potential negative environmental effects.
INSTRUMENTS/ Processes for implementation	• Smart waste: pay-as-you-throw (https://netzerocities.app/resource-2169) • Reducing demand for (over)packaging/ packaging waste, improved circular design and strategies that fully replace the need for packaging (https://netzerocities.app/resource-2453) • Capacity building for city officials to understand urban metabolisms and circular solution opportunities (https://netzerocities.app/resource-1568)

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Community composting	
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	***Climate and Geography:*** Community composting can be implemented anywhere, but climate plays a vital role as it both increases the time of decomposition and increases the cost of technologies that are required to be implemented in cold and humid, and hot and humid areas. Compost pile temperatures affect microbial growth and decomposition rate. Higher temperatures accelerate organic material breakdown, kill weed seeds, and kill pathogens. Extreme heat (>70 °C) inhibits microbial activity. The optimal temperature range is 40 °C to 65 °C. Using a thermometer, the composting temperature can be adjusted as needed. Aeration, turning, and changing pile moisture and size are common temperature-adjusting methods. ***Economic and social context:*** Poor management can lead to uncontrolled degradation of organic waste in containers, causing odours and leachate. Furthermore, logistic problems can lead to unsatisfactory implementations. New composting technologies should be well-addressed, and operational environment data should be thoroughly analysed for a win-win situation for all stakeholders.
IMPACTS (Indicators & DNSH)	***Emissions:*** Composting reduces greenhouse gas emissions and food waste. Food loss and waste account for 8–10% of global greenhouse gas emissions. Although EC (2010) reported significant methane and ammonia emissions for in-vessel composting, Andersen et al. (2012) report negligible ammonia emissions and variable methane emissions of 0.4–4.2 kg per tonne of wet Organic Household Waste (OHW). These emissions are highly dependent on process management and can be minimised under best practice. Considering the net impact on account of fertiliser replacement, avoided transport and adding carbon to soil. Community composting leads to relatively minor net burdens and a significant fossil resource depletion of -359 MJ equivalent per wet tonne of OHW composted if the avoidance of waste collection is considered. (Home and community composting- JRC, EC, 2022) ***Cost:*** The total investment can be divided among houses based on society's unit needs. Per household investment (a) Marketing & Literature: EUR 6; Net Bin Cost: EUR 3.38; Delivery and storage: EUR 14.86; Annualized Cost: EUR 2.50 (over 10 years)
	DNSH: **Pollution prevention and control**: Mixed organic waste can lead to the presence of tiny plastic particles in the compost, which will have a negative effect on its quality and, if used as manure (fertilisers) for food and vegetables, will degrade the quality of the soil. Additionally, if a compost pile is improperly aerated (anaerobic), which means oxygen isn't reaching the pile, it will emit methane gas harmful to the environment.
Additional information from CASE STUDIES	**Case Study community composting in San Francisco (USA)** San Francisco was the first US city to require composting. San Francisco adopted a 75% diversion by 2010 and zero waste goal in 2002. It exceeded the first goal two years early, recovering 80% and halving disposal. LA Compost started in 2013. First, volunteers collected "organics" on bicycles. Restaurants and juice bars composted food scraps at community members' homes. Funds from sales or donations at local farmers' markets went to school gardens. LA Compost launched local hubs in 2014. Each hub keeps organics in the community and offers a space to learn about composting. Local grants and businesses like Patagonia helped LA Compost expand. The community diverted over 360,000 kg of organics in 2021. **Home and Community composting in Porto (Portugal)** Terra à Terra promotes home composting in Lipor's municipalities to reduce organic waste. About 500,000 tons a year of municipal waste from Lipor's affiliated municipalities are collected, transported, treated, and disposed of. This involves: 13,905 composting bins distributed (1 per household/ institution); 75 composting

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Community composting	
	sites; 4,020 composting site and kitchen waste bucket support visits. Lipor conducted an online survey about the kitchen waste bucket in 2014. This method estimates bio-waste reduction per compost bin: 423 kg/compost bin per year, translating to 5 886 tons per year bio-waste reduction, 1,237 tonnes CO_2 per year. Gardens and urban farming use compost. **Community composting in Nitra (Slovakia)** Community Composting in Nitra, Slovakia, was launched in 2018 as a small-scale project for 50 households, whose final product – compost – serves involved households and public areas. Composting Community's project. Nitra Community Foundation's first grant was 4,000 EUR (3,000 for composter and 1,000 for promotion and composting accessories). Voluntary work has no costs. In 2020, another grant (1,000 EUR) funded lectures and guidelines. The city of Nitra began cooperating in 2020, and new composter sites were identified in 2021. The city is deploying 40 new composters. As part of informal environmental education, the city plans composting lectures.

3.6.13 Hard drainage-flood prevention

- Authors: **Tecnalia**
- Knowledge Repository link: https://netzerocities.app/resource-1308

Hard drainage-flood prevention

This NBS focuses on the delivery **additional ecological components** within a hard/built engineering approach to **water management**. They aid the **reduction in pluvial flood risk** in urban areas and improve the **quality of water** within sewerage systems.

The main **approaches and benefits** of hard drainage flood prevention are:

- Hard-drainage flood prevention includes **river engineering and dam construction** to control the amount of discharge.
- Dams can be built to hold water back and release it in a controlled way. Water is held in a reservoir behind the dam, and can provide an **additional use**, such as hydroelectric power or recreation.
- The **river channel** may be widened or deepened allowing it to carry more water. A river channel may be straightened so that water can travel faster along the course. The channel course of the river can also be altered, diverting flood waters away from settlements.

Considerations in designing hard drainage flood prevention: the dam specifications need to consider sediment trapping behind the dam wall, which can lead to erosion downstream. In addition, altering the river channel may lead to a greater risk of flooding downstream, as the water is carried there faster.

CO-BENEFITS	It can generate hydroelectric power.

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Hard drainage-flood prevention	
	It also **reduces the risk to natural and climate hazards,** by protecting from flood episodes, provides a regulated amount of water to surrounding areas for irrigation. Dams provide water balance in cases of extreme or irregular weather. It also contributes to a **better water management,** by offering the possibility to displace the water to dry areas when there are floods. It allows community to **collect fresh water** during rainy seasons for later use during droughts and dry spells, as well as provides water balance in case of extreme/irregular weather. It contributes to **enhancement stability of the urban infrastructure**, it may improve pedestrian access though footpaths, and it may offer facilities for anglers and mooring provision for the recreational and holiday boating industry. Another co-benefit is related to **species increase,** enhancing wetland habitats. It can also lead to an improvement in the extent and quality of natural habitats, and contributes to minimize losses due to floods.
EXTERNAL LINKS	• Hard drainage-flood prevention (URBAN GreenUP project) • Remus, J. I., & Jonas, M. (2010). River Engineering: Past, Present and Future–A Comprehensive Systems Approach
EXAMPLES	• Regional flood management by combining soft and hard engineering solutions, the Norfolk Broadlands (Climate Adapt)

Hard drainage-flood prevention	
PRE-CONDITIONS & ENABLING CONDITIONS	***Political***: Alignment among stakeholders: planning authorities, developers and landowners. ***Economic***: The primary cost are land acquisition and maintenance. ***Social***: The effective planning, design, construction and operation of urban Natural Water Retention Measures requires the involvement of a wide range of stakeholders. ***Technical***: Dimensions: retention of sediment behind the dam wall alters minimally the course of the water to avoid flooding. Not compatible with traditional solutions at historic centres and highly dense consolidated urban areas. Not possible to be implemented in case of existing underground facilities. ***Legal***: National and local instruments are the most widely effective for SUDs due to their wide-scale application at the household or very local level. Existing standards facilitate the development of the solution.
CONSTRAINTS/ BARRIERS for implementation	***Political***: No interaction between authorities and other stakeholders, lack of commitment, society pressure to avoid its construction. ***Economic***: Depends on resources availability for the investment, which is usually expensive. ***Social***: No participation to enhance the solution, no acceptance of society, displacement of the population, loss of vegetation. ***Technical***:

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Hard drainage-flood prevention	
	Lack of territory suitability, geomorphology, excessive elevation, small place. ***Legal****:* No planning instruments that support, prohibition to construct there due to protection regulations. ***Geographic:*** Conditioned by place, geomorphology and scale of implementation – there may be restrictions depending on the space to be implemented (urban x rural areas, dense x dispersed zones, etc.)
INSTRUMENTS/ Processes for implementation	• High level engineering knowledge to develop the project and implement the hard drainage. • Training of involved stakeholders • Incentives • Voluntary measures with stakeholders • Regulation and standards in place
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	This type of interventions has a very high cost, and it is difficult to get the investment recovery in a short term. The interventions usually create important modifications in the environment.
IMPACTS (Indicators & DNSH)	Protecting the community against floods and landslides, it contributes to the decrease of the potential vulnerability.
	DNSH – it contributes positively to the following objectives: • Climate change adaptation • The sustainable use and protection of water and marine resources • Pollution prevention and control to air, water or land • The protection and restoration of biodiversity and ecosystems
Additional information from CASE STUDIES	Hard drainage-flood prevention (URBAN GreenUP project) Remus, J. I., & Jonas, M. (2010). River Engineering: Past, Present and Future–A Comprehensive Systems Approach Hard drainage-flood prevention (URBAN GreenUP project) Remus, J. I., & Jonas, M. (2010). River Engineering: Past, Present and Future–A Comprehensive Systems Approach

3.6.14 Grassed swales and water retention pounds

- Authors: **Tecnalia**
- Knowledge Repository link: **https://netzerocities.app/resource-1318**

Grassed swales and water retention pounds
Swales are shallow, flat bottomed, vegetated open channels designed to convey, treat and often attenuate surface water runoff. When incorporated into site design, they can enhance the natural landscape and provide aesthetic and biodiversity benefits. They are often used to **drain roads, paths or car parks**, where it is convenient to collect distributed in flows of runoff, or as a means of conveying runoff on the surface while enhancing access corridors or other open space. Swales can have a variety of profiles, can be uniform or non-uniform, and can incorporate a range of different planting strategies, depending upon the site characteristics and system objectives.

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Grassed swales and water retention pounds

Grassed swales have the capability to reduce runoff volume and **improve water quality**. Volume reduction occurs primarily through infiltration into the soil, either as the waterflows over the slide slope perpendicular to the roadway into the swale or down the length of the swale parallel to the roadway. Pollutant removal can occur by sedimentation of solid particles onto the soil surface, filtration of solid particles by vegetation, or infiltration of dissolved pollutants (with stormwater) into the soil (Abidaand Sabourin, 2006). When **solid particles** settle to the soil surface or are captured by filtration on vegetation, the total suspended solids concentration of the runoff is reduced and overall water quality is improved as long as the solids do not become resuspended.

Retention ponds are ponds or pools designed with additional storage capacity to attenuate surface runoff during rainfall events. They consist of a permanent pond area with landscaped banks and surroundings to **provide additional storage capacity** during rainfall events. They are created by using an existing natural depression, by excavating a new depression, or by constructing embankments.

Retention ponds can provide both **storm water attenuation** and **water quality treatment** by providing additional storage capacity to retain runoff and release this at a controlled rate. Retention ponds have good capacity to remove urban pollutants and improve the quality of surface runoff.

CO-BENEFITS	
	• The enhancement of ponds will increase resource efficiency, allowing to **improve water quality**. • **Better water management**: Swales are intended to slow and store runoff. • **Better waste management**: Retention ponds are highly effective at intercepting sediment loading in runoff. • **Improve land use management**: Creation of new ponds will create new aquatic habitat increasing species. They are effective at storing runoff from small to medium drainage areas. • **Increased carbon sequestration capacity**: They may be useful to create aquatic and riparian habitat and therefore has the potential to increase natural biomass production. • **Reduce risk to natural and climate hazards**: Besides, they provide a contribution to adaptation to the higher intensity of storm events expected due to climate change.

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Grassed swales and water retention pounds	
	• **Improve air quality, Reduce GHG emissions**: Ponds can be effective in reducing urban diffuse pollution. Retention ponds can be effective at pollutant removal, particularly as a result of settling of particulate pollutants. • **Improvement in soil health**: Evapotranspiration in swales is more efficient than predicted by agricultural engineering. Swales with vegetation may retain sediment and particulate pollutants. • **Enhance stability of the urban infrastructure**: Swales provide a 'green' alternative to conventional drains. • **Species increase, pollinator increase**: They may enhance biodiversity in a more effective way, when making use of native vegetation. • **Decrease future maintenance costs**: Swales can provide a location for snow storage during winter months.
EXTERNAL LINKS	• Grassed swales and Water Retention Pounds (URBAN GreenUP project) • NWRM (2015) Retention Ponds • Wilson, S, Bray, B, Neesam, S, Bunn, S and Flanagan, E (2009) Sustainable Drainage: Cambridge Design and Adoption Guide • NWRM (2015) Swales • susDrain (2018) Component: Swales • Metropolitan Area Planning Council of Metropolitan Boston -Vegetated Swales (MAPC)
EXAMPLES	• Izmir - Turkey (URBAN GreenUP Project)

Grassed swales and water retention pounds	
PRE-CONDITIONS & ENABLING CONDITIONS	***Political***: Alignment between stakeholders: planning authorities, developers and landowners. ***Economic***: The primary cost are land acquisition and maintenance (avoiding ecosystem degradation, plagues and pollution). Availability of local incentives. Desirable the existence of resources to ecosystem restauration. ***Social***: The effective planning, design, construction and operation of urban Natural Water Retention Measures requires the involvement of a wide range of stakeholders. ***Technical***: Dimensions: space is required, which must be located at a low point in the catchment to receive drainage by gravity, needs site and slope stability, soil types and underlying geology. ***Legal***: National and local instruments are the most widely effective for SUDs due to their wide-scale application at the household or very local level. Compatibilities with the Spatial and Municipal Urban Plans and regulations for the implementation. Existing standards facilitate the development of the solution ***Additional considerations:*** • The topography of the site should generally allow for a longitudinal slope of no more than 4% and no less than 0,5%. Flatter slopes can result in ponding, while steeper slopes may result in erosion (depending on soil type, vegetation, and velocity) Use natural topographic low points and drainageways to minimize excavation. • Underlying soils should be a sandy loam or a similar soil type with no more than 20% clay. Soil augmentation may be necessary.

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Grassed swales and water retention pounds	
	• Side slopes should be 3:1 or flatter for maintenance and to prevent side slope erosion. Swale bottoms should generally be between 2 and 8 feet in width. • Use pea gravel diaphragms for lateral inflows. • Check dams can be utilized to establish multiple cells. Check dams at 50-foot intervals (<2' drop) help to maximize retention time, increase infiltration, promote particulate settling, and decrease flow velocities. Check dams are not necessary with very low longitudinal slopes. Provide for scour protection below check dam. • Outlet protection must be used at any discharge point from swales to prevent scour. • Select grass species that produce fine, uniform, and dense cover and that can withstand prevailing moisture conditions. • Temporary erosion and sediment controls should be utilized during construction. • Keep heavy equipment out of the channel during construction to minimize compaction. Even a bobcat grader can compact soils and reduce potential infiltration. Use excavator with a swing arm and work from the side of the swale. • Mulch anchoring should be done immediately after seeding.
CONSTRAINTS/ BARRIERS for implementation	***Political***: No interaction between authorities and other stakeholders ***Economic***: Lack of availability of investment. ***Social***: Lack of citizen participation to enhance the solution, or no acceptation of society. ***Technical***: Wrong election of the place, small area, no gravity to receive catchment, erosion, low stability. ***Legal***: Lack of a planning instruments that support SUDs. ***Additional considerations:*** • Vegetated swales work best in sandy loams that facilitate infiltration (very sandy soils may be prone to erosion under high runoff velocities). • Careful hydrologic design is necessary to ensure adequate pre-treatment of the water quality volume and non-erosive conveyance of large storms. • Each grassed swale can treat a relatively small drainage area of a few acres, depending on land-use and soil type. Large areas should be divided and treated using multiple swales. • Swales are impractical in areas with steep topography. • A thick vegetative cover is needed for these practices to function properly. Grass must not be mowed too short. • Swales should be used carefully on industrial sites or areas of higher pollutant concentrations. If used, they should be part of a "treatment train" that includes other treatment BMPs. • Swales can be subject to channelization, if erosive velocity is exceeded. • Soil compaction can reduce infiltration capacity. • Swales are not effective at reducing soluble nutrients such as phosphorous. • In some places, the use of swales is restricted by law; many local municipalities may require curb and gutter systems in residential areas.

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Grassed swales and water retention pounds	
INSTRUMENTS/ Processes for implementation	• Training • Incentives • Voluntary measures with stakeholders • Green Public Procurement
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	Vegetated swales can be easily implemented as they are linear structures, however, if combined with water retention ponds, surface requirements are larger. Depending on the initial state, it can take a long time for vegetation growth in the selected place.
IMPACTS (Indicators & DNSH)	Protecting the community against floods and landslides, it contributes to the decrease of the potential vulnerability.
	DNSH – it contributes positively to the following objectives: • Climate change adaptation • The sustainable use and protection of water and marine resources • Pollution prevention and control to air, water or land • The protection and restoration of biodiversity and ecosystems
Additional information from CASE STUDIES	Grassed swales and Water Retention Pounds (URBAN GreenUP project) NWRM (2015) Retention Ponds Wilson, S, Bray, B, Neesam, S, Bunn, S and Flanagan, E (2009) Sustainable Drainage: Cambridge Design and Adoption Guide NWRM (2015) Swales susDrain (2018) Component: Swales Metropolitan Area Planning Council of Metropolitan Boston - Vegetated Swales (MAPC) Izmir - Turkey (URBAN GreenUP Project) The **River Quaggy in London** is a river valley and natural flood plain which has fluvial flooding. **Fornebu, Norway | Natural Water Retention Measures** showed that brownfields can be successfully re-developed as sustainable multi-function urban areas supporting a range of recreational, residential and industrial land uses. Water retention spaces, reforestation and grazing management in **southern Portugal | Natural Water Retention Measures**.

3.6.15 Floodable park

- Authors: **Tecnalia**
- Knowledge Repository link: **https://netzerocities.app/resource-1328**

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the "orange" fields of this solution, and then it has been afterwards reviewed by JRC and completed the "pink" fields, and the Knowledge Repository content has been updated with JRC's input. So, here only the "orange" fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

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Floodable park

Floodable parks can be designed to **control flow rates** and **decrease flow peaks** by storing excess floodwater and releasing it slowly once the risk of flooding has passed. They are **innovative SUDs** that can play a particularly important role in mitigating potential impacts caused by surface run-off water from rain, flash floods or from small and medium sized water courses. It is important to consider the introduction of flood tolerant plants and the amount of ground excavated.

Moreover, **water retention spaces** should be lower than the rest ones with some elevation change. Among the potential benefits that floodable parks can provide are reducing the water flow entering the public sewerage system together with delivering leisure and recreational spaces providing the community better health and well-being, as well as and biodiversity benefits, such as shelter for aquatic birds.

CO-BENEFITS	• **Reduce flooding impacts** • Offer economic profit in a short-term • Support climate change adaptation and mitigation • Improve **aquatic ecosystems habitats** • Provide an opportunity to **reuse water** due to their retainment capacity • Contribute to **biodiversity** improvement • Create recreational areas for citizens
EXTERNAL LINKS	• Floodable Park (URBAN GreenUP project) • Floodable parks as a tool for local flood resilience (LGIU) • Floodable Park/ Water Square (Florida Department of Environmental Protection) • Massachusetts - Climate Action Tool. Manage floodwater: Create a floodable park or open space • A research of design in arid zones to prevent flood problems: design proposal for a floodable park in Chañara, Chile • The floodable park "La Marjal" (Alicante, South East Spain) as a paradigmatic example of water reuse and circular economy
EXAMPLES	• Alicante´s floodable urban park with a twist - La Marjal • Copenhagen Enghaveparken Park
PRE-CONDITIONS &	***Political***

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Floodable park	
ENABLING CONDITIONS	Alignment between stakeholders from planning authorities through to developers and land owners. ***Economic*** The primary cost is therefore the cost of land acquisition and maintenance cost. ***Social*** The effective planning, design, construction requires the involvement of a wide range of stakeholders. ***Technical*** Dimensions, retention of sediment behind the dam wall, alter minimally the course of the water to avoid flooding. ***Legal*** National and local instruments are the most widely effective for SuDS due to their wide-scale application at the household or very local level. The possibility of local incentives should always be explored.
CONSTRAINTS/ BARRIERS for implementation	***Political*** No interaction between authorities and other stakeholders, lack of commitment, society pressure to avoid its construction. Economic No investment, expensive. ***Social*** No participation to enhance the solution, no acceptation of society, displacement of the animals, loss of vegetation. ***Technical*** Lack of territory suitability, geomorphology, excessive elevation, small place, soil erosion, impermeable materials. ***Legal*** No planning instruments that support, prohibition to construct there due to protection figures.
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	In some cases in Chile due to the river pollution is not the best alternative to retain the waters. However, in Chañaral it has been positive, because it offers strategies to store water for periods of drought and using phytoremediation techniques to heal the soil. In Alicante it has provided a system for water treatment and water reuse, which is key due to the quantity of water they have during the year and the torrential precipitations. Besides it has recovered autochthonous vegetation and fauna. As well as a reduction of environment impact and economic cost for flooding impacts. Likewise, it has increased social commitment and tourism in the area.

3.6.16 Green pavements: hard drainage pavements, green parking pavements

- Authors: **LGI**
- Knowledge Repository link: **https://netzerocities.app/resource-1348**

Green pavements: hard drainage pavements, green parking pavements
Green Pavements and hard drainage pavements are particular types of pavements made out of a **porous concrete surface**, open pore pavers or asphalt, with an underlying stone reservoir or water

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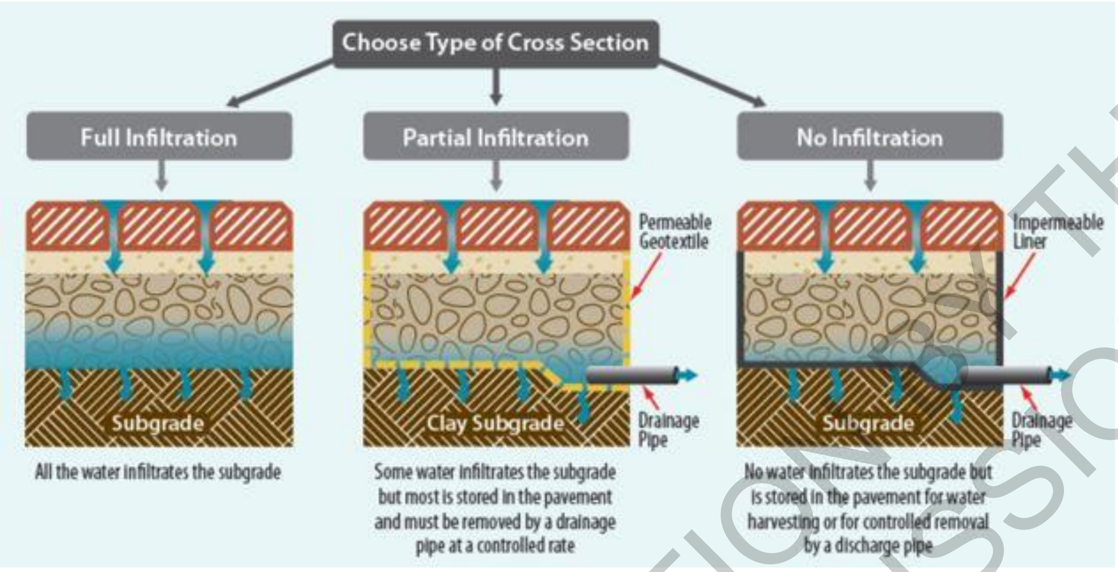
Green pavements: hard drainage pavements, green parking pavements

channels touching the soil. Those solutions allow **water to filter** on the inside and be absorbed by the ground -or drained via a drain tile- instead of running over.



Types of green pavements. Source: www.pavershare.org

Some types of green pavement may be:

- **Traditional Concrete/Asphalt:** the standard mix minus the fine particles which are left out to make it more porous,
- **Plastic Pavers:** the plastic grids have a honeycomb shape that allows vegetation, such as grass, to grow through the holes,
- **Concrete Pavers:** there are spaces between the concrete blocks which aid better drainage and water permeability,
- **Permeable interlocking concrete pavers:** concrete blocks leaving constant space to greenery.

The main **benefits** of the **green pavements for parking's** are related to the reduction of the overall quantity of net discards, conservation both material and energy for paving, provision of an easy way to make a substantial reduction in the overall volume of grey surface. While the hard drainage pavements have benefits such as the reduction of storm water runoff and therefore floodings, the mitigation of heat island effect, or cooling temperatures; besides that green pavement provides a better traction.

Its main **application** in urban environment is for cities, smaller municipalities and highways (parking lots, sidewalks, low-traffic areas and driveways). They both minimize expenses and improve aesthetic.

CO-BENEFITS	The co-benefits of the green pavements are related to **better water management,** since the captured rain in an infiltration trenches or rainwater harvesting system reduces the overall volume of stormwater by storing it and using it for toilet flushing, gardening, car washing and cooling air conditioning units. Improve land use management; **improvement in soil health**, **reducing noise pollution**, **reduction of hot spots/urban heat islands** in the city. They also contribute to a **reduction of road danger**, since the hard drainage increases friction and avoids aqua-planning; as well as to a **better physical activity** for individuals: the softer surfaces other than absorbing air also provide a better surface for walking and running, limiting articulation damages. They also **enhance attractiveness of the city** and increase **biodiversity**.
KEYWORDS	Green parking pavements are related to other water interventions, such as water leaks detection, WWTP water reuse and recycling (urban irrigation) and tertiary treatments, urban metabolism mapping, rain gardens, SUD (sustainable urban

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Green pavements: hard drainage pavements, green parking pavements	
	drainage) systems. As well as to other solutions related to urban carbon storage and sequestration such as smart-soils and phytoremediation.
EXTERNAL LINKS	• Hard drainage pavements (URBAN GreenUP project) • Permeable Pavement: the pros and cons you need to know (GreenBlue Urban) • Sustainable road construction: current practice and future concepts (World Highways) • Hard Sustainable Drainage Infrastructure in the Urban Environment (Foundation for Water Research) • Healthy Benefits of Green Infrastructure in Communities (EPA: Environmental Protection Agency)

Green pavements: hard drainage pavements, green parking pavements	
PRE-CONDITIONS & ENABLING CONDITIONS	***Site assessment:*** Determine the location of implementation based on the run-off area, the catchment area, the surface slope and whether it is part of a larger rainwater framework, Gather sufficient knowledge in ecology and pedology to assess the site conditions Ensure the appropriate location and distance with building foundation and/or any other wells with drinking water The level of groundwater table should be checked before implementing green pavement to prevent pollution ***Governance:*** Bring together a multidisciplinary team (hydraulic engineer, urban planner, architect, ecologist) Ensure the project is supported over the long term by the project owner, from its design to its implementation Anticipate the future management of the project
CONSTRAINTS/ BARRIERS for implementation	Lack of Government Staff Capacity and Resources Perception of normative conflict Unfamiliarity with Maintenance Requirements and Costs Scepticism about Long-Term Performance
INSTRUMENTS/ Processes for implementation	• Capacity building and engagement with municipalities to identify and co-create circular solutions and roadmaps • Engagement, co-creation and co-design of NBS and Green Infrastructure plans and interventions • City coaching in NBS • Platform for Enhancing Multi Stakeholder Dialogue to Implement NBS across EU • Integrated land use and urban planning with energy and climate • Integrated land use planning and urban space management with mobility planning • Integrated climate plans for cities (i.e.: SECAPs) • City water resilience assessment • Public procurement for innovative NBS and Green Infrastructure interventions • NBS and Green Infrastructure regulation and ordinances • NBS and Green Infrastructure plans and strategy design and governance • Building Material Passport (BIM-based) • NBS and Green Infrastructure Mapping • Circular economy design principles to increase the durability, reparability, upgradability or reusability of products • Circular Life Cycle Assessment/Analysis for material and products
DRAWBACKS/ ADVERSE	***Cost:*** More implementation is more expensive than conventional pavements.

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Green pavements: hard drainage pavements, green parking pavements	
IMPACTS of the solutions after implementation	***Maintenance:*** Prone to clogging, sand between the pavers must be removed using an industrial vacuum. If not maintained properly, may cause water and pollutants to run off the surface. ***Solidity:*** Not as strong as traditional pavements, green pavement is not suitable for a repeated passage of heavy vehicles.
IMPACTS (Indicators & DNSH)	Growable surface (pcs/m2) Water infiltration Maintenance costs

3.6.17 Sustainable Urban Drainage Systems (SuDS)

- Authors: **CARTIF**
- Knowledge Repository link: https://netzerocities.app/resource-1358

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the "orange" fields of this solution, and then it has been afterwards reviewed by JRC and completed the "pink" fields, and the Knowledge Repository content has been updated with JRC's input. So, here only the "orange" fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

Sustainable Urban Drainage Systems (SuDS)
SuDS are drainage systems that are considered to be environmentally beneficial, causing minimal or no long-term detrimental damage. They are often regarded as a sequence of management practices, control structures and strategies designed to **efficiently and sustainably drain surface water**, while minimising pollution and managing the impact on water quality of local water bodies.  Urban Catchment Forestry (SuDS). Source: URBAN GreenUP (H2020 Project GA No 730426) and Liverpool City Council SuDS take inspiration from **natural features and processes** like uptake of water by plants, soil infiltration, pools, ponds, marshes, wetlands, springs, streams and rivers.

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Sustainable Urban Drainage Systems (SuDS)	
SuDS can take **many forms**, both above and below ground. Some types of SuDS include **planting**, others include proprietary/**manufactured products**. In general terms, SuDS that are designed to manage and use **rainwater** close to where it falls, on the surface and incorporating vegetation, tend to provide the greatest benefits. Most SuDS schemes use a combination of SuDS components to achieve the overall design objectives for the site.	
CO-BENEFITS	SuDS contribute to climate adaptation by **reducing the risk of natural and climatic hazards**, related to heavy rainfall events. The approach involves slowing down and reducing the quantity of surface water runoff from a developed area to manage downstream flood risk, and reducing the risk of that runoff causing pollution. Rainwater management through SuDS relieves pressure on water treatment plants, thus contributing to **better water management**. The accumulation of stagnant water pools is linked to the presence of disease vectors such mosquitoes. Water management through SuDs helps to **reduce the risk of such epidemics**.
EXTERNAL LINKS	• SUDS (URBAN GreenUP project) • Urban catchment forestry (URBAN GreenUP project) • Grassed swales and water retention pounds (URBAN GreenUP project)

3.6.18 Water irrigation and maintenance technologies

- Authors: **CARTIF**
- Knowledge Repository link: **https://netzerocities.app/resource-1368**

Water irrigation and maintenance technologies

The needs of sustainable and climate resilience cities are driven along with social, ecological and technological transformations. In recent years, technological advances have increased remarkably, which has prompted the exploration of how urban systems can be transformed into "smart cities". The use of information and communications technologies, the Internet of Things, and robotic systems and artificial intelligence have enabled the creation of "smart" technologies to monitor and manage nature-based solutions.

Source: University of Leeds - A robotic revolution for urban nature

The different technologies provide **monitoring data in real time** so that aspects such as **soil moisture**, **rainfall flows**, **permeability capacity** or the water table can be analysed and resolved quickly and efficiently, reducing possible damage and inconvenience that can occur cause in the day to day of the cities.

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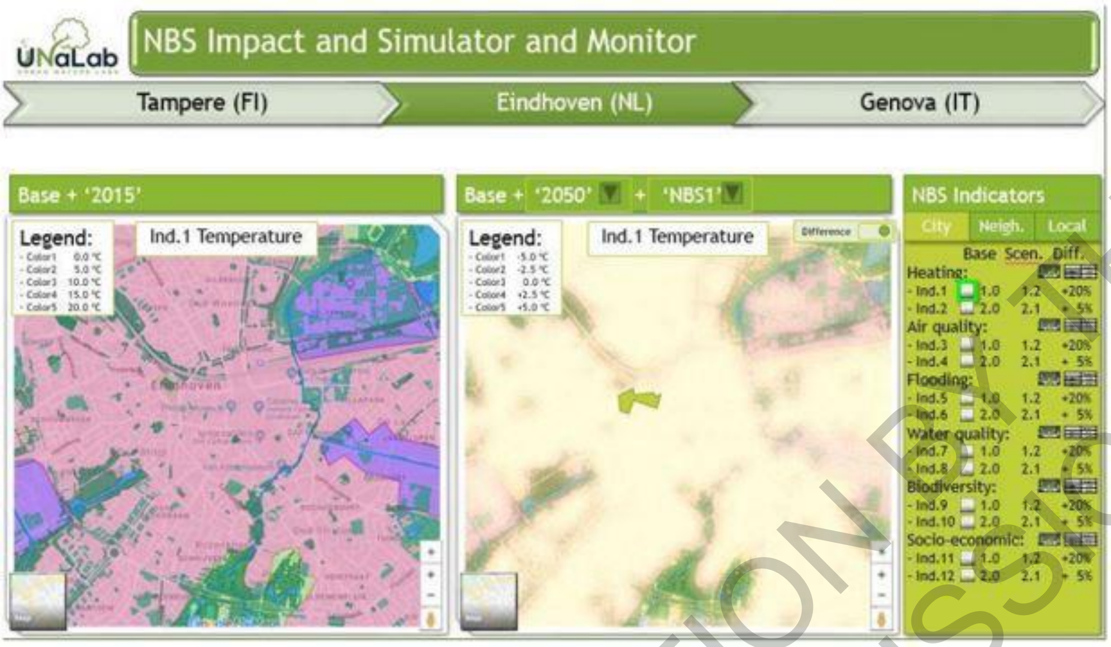
Water irrigation and maintenance technologies



NBS Impact and Simulator and Monitor. Source: UNaLab project (Link)

Assigning and defining some parameters, based on previous studies of the areas where the NBS are going to be implemented, together with real-time monitoring data, allows administrators to plan different management techniques with different intensity and frequency. Over time, this allows for reductions in budgets dedicated to maintenance.

Monitoring and tracking each site, documenting changes, problems encountered and how they are resolved, along with proper communication and training of maintainers will help find the perfectly balanced management for each specific site.

CO-BENEFITS	Through the use of technology for water irrigation and maintenance, it is achieved **water resource efficiency** (better water quality and better water management).
EXTERNAL LINKS	• Smart Technologies for NBS (Connecting Nature project) • Li, J., and J. I. Nassauer. 2021. Technology in support of nature-based solutions requires understanding everyday experiences. Ecology and Society 26(4):35. • NBS multi-scalar and multi-thematic typology and associated (Appendix 3: NBS Factsheets) - Nature4Cities project

Water irrigation and maintenance technologies	
PRE-CONDITIONS & ENABLING CONDITIONS	***Climate and Geography:*** Nature based solutions are little by little incorporated to the urban areas, the city is an ecosystem with their flows and ecosystem services where humans develop their activities. NBS that incorporate "smart" technologies improve the experience. Through the use of technology for water irrigation and maintenance, it is achieved water resource efficiency (better water quality and better water management). ***Urban Form and layout:*** The maintenance and management of green areas has always been a problem for administrations, so the incorporation of these solutions, especially in the area of irrigation, is very useful for them. ***Technical aspects/infrastructure:***

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Water irrigation and maintenance technologies	
	With a simple APP you can monitor the NBS, whether it is working properly or if it has stopped watering, even adjusting the irrigation to the precipitation automatically. ***Policy and regulatory/legal framework:*** The needs of sustainable and climate resilience cities are driven along with social, ecological and technological transformations. In recent years, technological advances have increased remarkably, which has prompted the exploration of how urban systems can be transformed into "smart cities". The use of information and communications technologies, the Internet of Things, and robotic systems and artificial intelligence have enabled the creation of "smart" technologies to monitor and manage nature-based solutions. ***Funding and financing:*** These systems make the green infrastructure more expensive to maintain but water and fertilizer consumption would also be decreased also reduce the maintenance hours, so the number of people employed is reduced, instead there must be at least one specialized person. The financing of these systems is either at the same time as the green infrastructure is installed, or if it has to be installed later, it can be financed through climate impact reduction policies, water saving, among others. ***Economic and social context:*** "Smart" technologies (information and communications technologies, the Internet of Things and robotic systems and artificial intelligence) used to monitor and manage nature-based solutions have enabled access to real-time data to optimize the process and reduce potential damage and inconvenience. ***Project governance and implementation modalities:*** These systems reduce complaints from neighbours about water wastage, as well as promoting skilled green jobs.
CONSTRAINTS/ BARRIERS for implementation	***Climate and Geography & Urban Form and layout:*** The current landscape makes these technologies absolutely necessary. The use of irrigation on roofs and facades increases the ambient humidity and reduces the temperature, thus reducing the heat island effect and increasing the habitability of cities plants of the city centre should be adapted for this purpose. Landscaping varieties should be developed for green open spaces that can withstand the new conditions of rainfall and temperature, leaving nature to nature ***Technical aspects/infrastructure & Economic and social context:*** Most of these systems are wireless, they use a GPRS network or WIFI, so distances must be taken into account for the signal to be effective. These systems are expensive and sometimes give problems at the most inopportune time (holidays, weekends), good maintenance and knowledge of their use is necessary.
INSTRUMENTS/ Processes for implementation	• User Engagement for Energy Performance Improvement https://netzerocities.app/resource-1498 • Supporting municipalities to monitor resource flows in line with impact targets and measurement processes https://netzerocities.app/resource-1528 • Capacity building and training https://netzerocities.app/resource-1578 • Integrated land use and urban planning with energy and climate https://netzerocities.app/resource-1678 • City water resilience assessment https://netzerocities.app/resource-1738 • Public procurement for innovative NBS and Green Infrastructure interventions https://netzerocities.app/resource-588 • NBS and Green Infrastructure regulation and ordinances https://netzerocities.app/resource-1813

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Water irrigation and maintenance technologies

- NBS and Green Infrastructure plans and strategy design and governance https://netzerocities.app/resource-1823

DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation

Climate and Geography:
The different technologies provide monitoring data in real time so that aspects such as soil moisture, rainfall flows, permeability capacity or the water table can be analysed and resolved quickly and efficiently, reducing possible damage and inconvenience that can occur cause in the day to day of the cities.
Assigning and defining some parameters, based on previous studies of the areas where the NBS are going to be implemented, together with real-time monitoring data, allows administrators to plan different management techniques with different intensity and frequency. Over time, this allows for reductions in budgets dedicated to maintenance.
Monitoring and tracking each site, documenting changes, problems encountered and how they are resolved, along with proper communication and training of maintainers will help find the perfectly balanced management for each specific site.

Technical aspects/infrastructure & Economic and social context:
The combination of innovative technology and sustainability and climate resilience makes the city a complex social-ecological-technological system.
Smart technologies for real-time monitoring and autonomous to manage NBS has social impact, making pleasant experiences of urban nature and their related well-being benefits and social and cultural values, for example, the possibility that this technology could be used to warn and control torrential rain, avoiding the flooding of certain areas.

IMPACTS (Indicators & DNSH)

The water management indicators address the potential benefits, co-benefits, and trade-offs associated with changes to surface water runoff volume and to water quality also wide range of applicable metrics for the assessment of NBS impact from a broad perspective, further exploring potential impacts on soil-water interactions, additional aspects of stormwater and excess runoff management, and actions pertinent to the implementation of the Water Framework Directive, including quantitative, hydro-morphological, ecological and physico-chemical status of surface and groundwaters.

Table 4-2. Indicators related to Water Management classified as structural (S), process focused (P) or outcome-based (O) indicators and their general applicability to different types of NBS

No.	Indicator	Units	Class	Applicability to NBS†		
				Type 1	Type 2	Type 3
RECOMMENDED						
3.1	Surface runoff in relation to precipitation quantity	mm/%	O	•	•	•
3.2	Water quality: general urban	various	O	•	•	•
3.3	Water quality: TSS content	mg/L	O	•	•	•
3.4	Nitrogen and phosphorus concentration or load	%	O	•	•	•
3.5	Metal concentration or load	%	O	•	•	•
3.6	Water quality: total faecal coliform bacteria content of NBS effluents	No.	O	•	•	•

Indicators related to Water Management. Source: Handbook for practitioners

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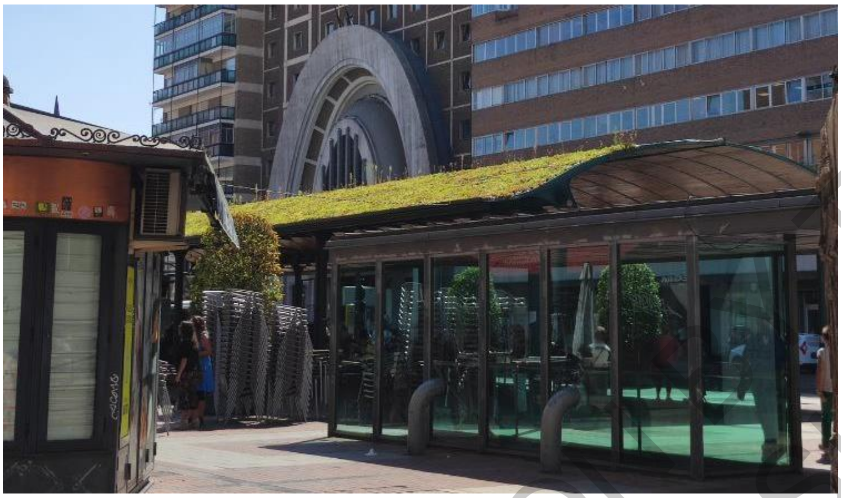
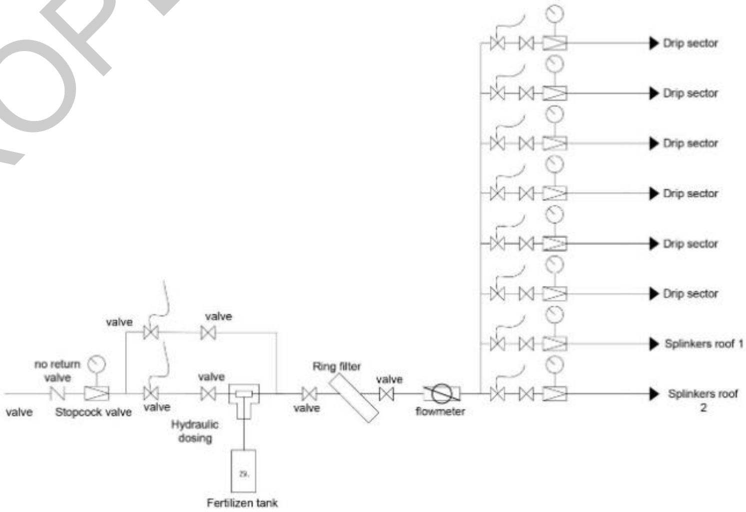
<table>
<tr><th colspan="2">Water irrigation and maintenance technologies</th></tr>
<tr><td>Additional information from CASE STUDIES</td><td>Technical specifications of Green Covering Shelter installed in Valladolid as part of the URBAN GreenUP project.

Green covering shelter in Valladolid (Source: María González (CARTIF)).


Elevation of the Plaza España green covering shelter (Source: SingularGreen).


Green Covering Shelter irrigation scheme (Source: SingularGreen)</td></tr>
</table>

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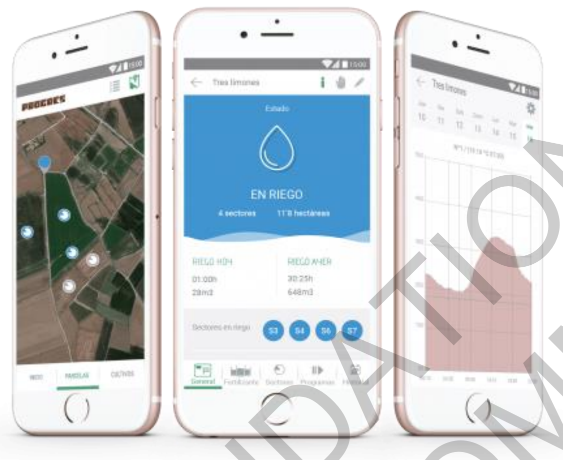
Water irrigation and maintenance technologies

Green Covering Shelter	unit	quantity	Price (€)	Amount (€)
Inert substrate, vegetation and drip irrigation pipes	m^2	488	77,91	38.022,11
Waterproofing	m^2	789,20	22,97	18.127,92
Lifeline	m	2	791,00	1.582,00
Connection to water and electricity	ud	1	3.000,00	3.000,00
Adaptation of the cupboard for irrigation station	unit	1	3.000,00	3.000,00
Total budget of material execution (€)				**63.732,03**
Tender budget with VAT (€)				**91.767,75**

Green covering shelter budget (Source: SingularGreen)



Example of irrigation control of a NBS (Source: Agronic)

Connecting Nature Enterprise Platform

Li, J., and J. I. Nassauer. 2021. Technology in support of nature-based solutions requires understanding everyday experiences. Ecology and Society 26(4):35. https://doi.org/10.5751/ES-12838-260435

Nature4Cities – D1.1 – NBS multi-scalar and multi-thematic typology and associated. Appendix 3. NBS Factsheets

3.6.19 Constructed wetland

- Authors: **Resilient Cities Network**
- Knowledge Repository link: **https://netzerocities.app/resource-1378**

Constructed wetland

Urban runoff can contribute to flooding and abrupt contribution to flow in peri-urban/urban streams. It is also frequently characterized by poor water quality, as runoff might contain a mix of contaminated sediments, pollutants, oils through to fertilizers and pesticides if these are not properly applied. In order to meet such challenges, alternative solutions exist, such as the one specified below.

Constructed Wetlands (CW) are fully engineered systems using natural processes to **treat water** for household (blackwater or greywater) and/or biodegradable municipal or industrial wastewater, as well as manage runoff. They use **wetland vegetation**, **soils**, and their associated **microbial assemblages** to assist in treating wastewater.

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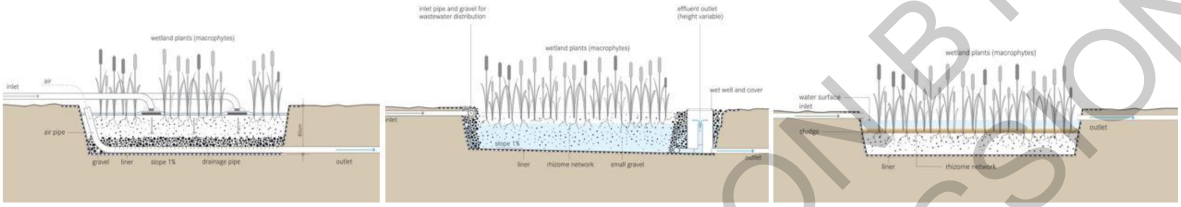
Constructed wetland

CWs can be classified into two variants:

- **Subsurface constructed wetland**: in this category of CW, the flow of wastewater occurs between the roots of the plants and there is no water surfacing (it is kept below gravel). The subsurface constructed can be classified into two categories:
    - **Vertical** subsurface flow constructed wetland: wastewater moves vertically from the planted layer down through the substrate;
    - **Horizontal** flow constructed wetland: wastewater moves horizontally via gravity, parallel to the surface. In this case, the wastewater is fed at the inlet and slowly flows horizontally through a porous media in which emergent vegetation is planted.
- **Free water surface constructed wetland**, that allows water to flow above ground exposed to the atmosphere and to direct sunlight. It creates therefore an open water areas that contain floating, submerged, and emergent plants. This type of CW is usually for tertiary treatment of previously treated water.



Scheme of vertical subsurface flow CW, horizontal subsurface flow CW, and free water. Source: Qunli

In terms of mitigation, constructed wetland have the potential to **sequestrate the carbon**. However, they need to be designed properly, so as to minimise methane and nitroxid emissions, which will depend on a multitude of factors (type of CW, used plants, flow mode of wastewater, etc.).

In terms of adaptation, constructed wetland allows to reduce moderately the heat urban island, due to the cooling role played by plants and water. Constructed wetland contribute to **reduce flood risk**, by reducing the volume of water in drainage networks during events.

Stormwater Wetland Park - Turenscape (China). Source: www.archdaily.com

Constructed wetland has also co-benefits in terms of **biodiversity** and **quality of water** returned to the environment. Wetland integration in the urban environment requires a good understanding of the hydrological regime, as well as spatial integration as a landscape piece of infrastructure. Once implemented, a constructed wetland will require careful maintenance and management.

CO-BENEFITS	In terms of **biodiversity**, constructed wetland host biodiverse communities and can restore ecological continuity (connection between natural areas for the benefit of animal and plant species). In terms of health, they improve the **quality of the water** returned to the environment. Constructed wetlands **improve the well-being** of citizens by

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Constructed wetland	
	providing access to a natural environment near or within the city. They have an educational value for the neighbouring communities.
EXTERNAL LINKS	• The SuDS Manual - Chapter 23: Ponds and wetlands (CIRIA) • Constructed Wetlands (EPA: Environmental Protection Agency) • NBS multi-scalar and multi-thematic typology and associated database, 2016, pp. 313-319 (Nature4Cities project)

Constructed wetland	
PRE-CONDITIONS & ENABLING CONDITIONS	***Climate and Geography:*** A deep understanding of the ecological, hydrological and hydrogeochemical functioning of the watershed is necessary for an appropriate design (both in terms of dimensioning, residence times but most importantly biological processes). Typically, relevant pollution management policy tends to provide the incentives for on-site management through wetlands (founded on the "polluter pays" principle). Valuing the co-benefits can stimulate such sustainable blue infrastructure development.
CONSTRAINTS/ BARRIERS for implementation	***Urban Form and layout:*** Land availability is a primary pre-requisite. ***Project governance:*** Politics of real estate is commonly a barrier to the development of constructed wetlands. Lack of clear construction and maintenance responsibility is also a common governance challenge. Multi-stakeholder participation and agreement is typically needed. This has also implications for the financing of the project (real estate, capital and maintenance expenditures). ***Technical aspects:*** Technical capabilities for developing such schemes are not always available and typically this will depend on the country context. The multi-disciplinary nature of these schemes (ecology, hydrology, engineering), as well as the limited availability of monitoring data from case studies, make design and implementation more challenging - thus considered riskier compared to traditional engineering approaches. Worth mentioning, technologies are still evolving but still require field-scale testing, i.e. real settings.
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	Wetlands are typically associated with the emission of GHG, particularly methane. A comparative life-cycle assessment should be carried out with alternative traditional engineering measures to assess contributions to net-zero. See [1] Monitoring is typically limited to verify the functioning of the scheme and development of possible adaptation measures (including maintenance approaches), in particular long-term monitoring. See [2], [3], [4]. [1] D. de la Varga, I. Ruiz, J.A. Álvarez, M. Soto, Methane and carbon dioxide emissions from constructed wetlands receiving anaerobically pretreated sewage, Science of The Total Environment, Volume 538, 2015, Pages 824-833, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2015.08.090. [2] Guidance manual for constructed wetlands, (Middlesex Universit, 2003). [3] Wetlands: operation and maintenance guide, (Auckland Council, 2004). [4] Constructed wetlands manual, (UN Human settlements programme, 2008).
IMPACTS (Indicators & DNSH)	GHG emissions, particularly methane (eq tons CO_2); ecological biodiversity and ecosystem protection indicators, flood risk reduction (as part of climate adaptation)
	While contributing to pollution prevention, and the protection and restoration of ecosystems, wetlands are associated with GHG emissions. As mentioned above, these must be compared through LCA with alternative measures to prevent pollution and protect ecosystems. Indicative KPIs:

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Constructed wetland	
	• KPI1: ecosystem quality biodiversity increase • KPI2: emissions generated • KPI3: water storage to reduce flooding • KPI4: water quality improvement (against baseline) • KPI5: social amenity (users and perceived value)

3.6.20 Rain garden

- Authors: **CEREMA**
- Knowledge Repository link: **https://netzerocities.app/resource-1388**

Rain garden

In urban areas, **rainwater** falls and runs off mineralized surfaces (asphalt, concrete, bitumen, etc.). For cities, this generates **problems** in terms of:

- **water pollution**: instead of being absorbed by the soil, rainwater is loaded with pollutants from the leaching of the impermeable surfaces on which it runs;
- **flooding**, due to an excessive volume of runoff water that can clog up the existing sewage system.

This is why there are **integrated rainwater management techniques** at the plot level, which improve water quality and reduce the volumes and flows discharged into the networks.

Rain garden. Source: URBAN GreenUP project

A **rain garden** is a shallow basin designed to collect, store, filter and treat runoff water. To optimize its functions, it should include a mixture of porous soils, native vegetation and some hyper-accumulative plants capable of phytomediation. This type of design is more or less complex, ranging from a simple sunken garden at the foot of a house to an earthwork system managing water from a stream. It should also be noted that, depending on the definition, the rain garden can cover vegetated landscaping such as ditches, valleys or basins (wet or dry).

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Rain garden

A rain garden can take the form of a series of planted basins, as seen here in the redesigned courtyard of the Lycée Saint Exupéry, Lyon, France. Source: Cerema

In terms of **mitigation**, the rain garden allows for **carbon storage** at the plant level, thanks in particular to photosynthesis which transforms carbon dioxide into organic matter. It should be noted that if we reason in terms of carbon footprint, like any development project, the construction of the rain garden may generate GHG emissions (earthworks, travel generated by the site, etc.), potentially offset by the carbon stored throughout the development.

In terms of **adaptation**, the rain garden contributes to **cooling urban spaces** and therefore to **reducing heat island effect** and overheating zones. The rain garden creates small wetlands, which have a cooling effect through water evaporation and evapotranspiration from the plants.

Whatever its form or size, the rain garden has many co-benefits:

- in terms of **water resources**: managing rainwater in a localised, economical way and as much as possible independently of underground networks;
- in **social terms**: giving visibility to the natural water cycle in an educational approach, improving social cohesion (gender, minority group);
- in terms of **biodiversity**: promote biodiversity in urbanised areas;
- in terms of **health (well-being)**: improving the living environment by associating water and plants, providing relaxation and well-being.

CO-BENEFITS

In terms of **resource efficiency**, the rain garden **reduces the volume of runoff water**, which can clog existing sewage systems causing overflows and flooding. The rain garden also improves the **quality of the water** resource by limiting the leaching of pollutants by rainwater runoff.

In terms of **health**, the rain garden is a landscape amenity that plays a positive role in **well-being and social cohesion** (gender, minority groups). For example, when a school yard is renovated and a rain garden is integrated, a process of re-appropriation of the space and transformation of uses takes place. Boys and girls play together more than in a traditional asphalt courtyard, where there are boys playing football on one side and girls on the other. The construction of a rain garden thus considerably transforms the atmosphere of the courtyard, which also becomes an attractive space for relaxation.

In **social** terms, the rain garden is a space for **awareness-raising** and pedagogy that promotes **behavioural change**. The rain garden gives visibility to water and its cycle, which is usually hidden or diverted, even though it is a fundamental element of our lives. This type of development thus makes it possible to raise awareness (via signs, communication, support, kits, etc.), and even to make the population of the neighbourhoods responsible for the management of "their" water.

In terms of **biodiversity**, the rain garden is an opportunity to encourage nature in the city and ultimately to increase the presence of species and **ecological**

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Rain garden	
	connectivity. A specific fauna and flora develop there. These facilities present strong challenges for the preservation of biodiversity in the city, particularly when they are connected to each other in a network with green spaces or natural areas. This ensemble then forms an essential network for biodiversity: the **urban green and blue grid**, which makes it possible to create or restore the ecological continuities essential to species and biodiversity.
EXTERNAL LINKS	• Rhône-Alpes research group on infrastructures and water (website): GRAIE • Programme of the city of Seattle (USA) to encourage the creation of rain gardens in private homes • Cleanwater, a programme for building capacity for integrated water management, from Melbourne Water (Australia)

Rain garden	
PRE-CONDITIONS & ENABLING CONDITIONS	Rain garden are small and planted depressions in the ground that collect rainwater and are used for water infiltration or to store water before being slowly released into the network. They are considered as low impact development. They can be designed in a variety of forms, are not very technical, and should be an integrated part of the design of a site. They are designed primarily to manage rainwater in urbanised areas. But beyond this hydraulic aspect, they offer a real added value on other services. ***Site assessment:*** Determine the location of the rain garden based on the run-off area, the catchment area, the surface slope and whether it is part of a larger rainwater framework, Design the project based on the diagnosis of landscape and integrating environmental and social dimensions while choosing the location of the rain garden, Gather sufficient knowledge in ecology and pedology to assess the site conditions Ensure the appropriate location and distance with building foundation and/or any other wells with drinking water The level of groundwater table should be checked before implementing rain garden to prevent pollution Choice of the right plant and grass according to the local climate ***Governance:*** Bring together a multidisciplinary team (hydraulic engineer, urban planner, architect, landscape architect, ecologist) Define a set of specifications aiming at a multifunctional approach, to be a common thread of the project Ensure the project is supported over the long term by the project owner, from its design to its implementation Anticipate the future management of the project
CONSTRAINTS/ BARRIERS for implementation	***Social integration:*** Involving city dwellers in stormwater management is now a necessity. But developing framework dedicated to public participation raises new challenges to local authorities: How to analyze the opportunity and feasibility to launch incentive programs to mobilize citizens in stormwater management? What stakeholders and decision-making processes to be involved? Which measures should be encouraged, according to what criteria? What types of incentives, should be prioritized especially financial ones? What kind of support should be put into place to foster the success of such programs? How to evaluate the results of the incentive programs?
DRAWBACKS/ ADVERSE IMPACTS of the	As low impact development practices, rain gardens have few disadvantages as long as their design, implementation and management are well anticipated.

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Rain garden	
solutions after implementation	Multifunctionality of rain gardens need to anticipate any limitations of uses or risks of conflicts that may occur once implemented (and therefore the importance to involve citizens at the design stage) Lack of appropriate management can disturb the performance of the rain garden (therefore the need of landscaping, pruning, removal of invasive species, removal of dead branches / vegetation) etc). If the rain garden is not functioning properly, water will get accumulated and can lead to flooding. Regular monitoring of the rain garden should be undertaken to prevent erosion and check sedimentation accumulation Garbage dumping should be prevented as well. Overflow if the capacity of the rain garden is exceeded
IMPACTS (Indicators & DNSH)	Flood risk reduction (as part of climate adaptation), ecological biodiversity
	Indicative KPI: • Water storage to reduce flooding • Soil porosity • Presence of vegetation • Social amenity (users and perceived value)
Additional information from CASE STUDIES	(Fr) The website of the Rhône-Alpes research group on infrastructures and water: GRAIE (En) The program of the city of Seattle (USA) to encourage the realization of rain gardens at home 700million gallons project (En) Cleanwater, a program of Melbourne Water, the water agency of the State of Victoria (Australia) (En) 12 000 rain garden (https://www.12000raingardens.org/): The 12,000 Rain Garden campaign is a cooperative effort with local partners lead by Stewardship Partners and Washington State University Extension. The campaign promotes rain gardens to address significant problems on priority streams and marine shorelines caused by untreated, uncontrolled runoff. The online platform gathers information and resources, including in-person events and trainings for people interested in learning to build rain gardens.

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3.7 Digital Solutions

- **Knowledge Repository: Digital Solutions:** https://netzerocities.app/resource-2645

Table 9: Digital solutions

Digital Solutions		Section
Analytics modelling solutions	Predictive Modelling	3.7.1
	Digital Twin (Built environment)	¡Error! No se encuentra el origen de la referencia.
	Local Digital Twin (Planning / Decision Making, cross-cutting)	¡Error! No se encuentra el origen de la referencia.
	Scenario-based analysis (Mobility & Energy - One Model)	3.7.4
	Artificial Intelligence (AI) applications to climate neutrality	3.7.5
	GHG Monitoring from Space	3.7.6
	BIM and CIM (Building/City Information Model)	3.7.7
Urban Digital Platforms	Platform Architecture	3.7.8
	CO_2 Emission Trading Platforms	3.7.9
	City Dashboards	3.7.10
	Predictive Maintenance supporting tools	3.7.11
	Advanced Renovation Support	3.7.12
	Data and Solution Catalogues	3.7.13
Digital infrastructure	IoT Sensor & Edge Computing for Environmental Monitoring	3.7.14
Disaster and Resilience Management	Vulnerability and risk information systems	3.7.15
	Satellite and Geospatial Data	3.7.16
E-governance solutions	Citizen Participation Platforms	3.7.17
Digital Public Goods	Measuring & Monitoring (green & digital transition)	¡Error! No se encuentra el origen de la referencia.
	Public Code Management	3.7.18
	Documentation of ownership of data	3.7.19
	Applying Open Standards	3.7.20
	Open Data Models & Ontologies	3.7.21
	Local Data Spaces Policy	3.7.22
	Living.in-EU / MIM Plus	3.7.23
	European Interoperability Framework for Smart Cities and Communities: EIF4SCC	3.7.24
	United for Smart Sustainable Cities (U4SSC) Publications	3.7.25

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Digital Solutions		Section
	Agile systems development (prototyping & sandboxes)	3.7.26
		3.7.27

3.7.1 Predictive Modelling

- Authors: **TNO**
- Knowledge Repository link: https://netzerocities.app/resource-1955

Predictive Modelling	
Predictive modelling is a crucial element for both **real-time management** and **long-term planning** in urban areas. For example, road sensor data can be used for real-time **traffic management** in a city, while predictions based on this data can enable decision makers to study long-term effects of interventions in a city. Typically, predictive modelling is performed for one domain in isolation, such as traffic predictions. However, for an **integral view** on a city it is important to combine such predictions with other domains such as air pollution, noise and behaviour of a population in a city.  *Examples of different ways to simulate and measure impact with Urban Strategy (TNO)* **Combining data and simulation models** could be part of such a method so as to accelerate and improve spatial planning in the urban environment. Furthermore, prediction models from the field of (explainable) AI can provide stakeholders not only with a prediction, but also with a justification of the underlying mechanisms. As a result, stakeholders can interact with real-time data and predictions simultaneously in several domains.	
CO-BENEFITS	Predictive modelling allows to investigate what-if scenarios on various aspects of the urban environment. This includes measures that **enhance the attractiveness of the cities**, **improve air quality** or **reduce energy needs** and **noise levels**. Interactive models and tools can calculate various KPIs on these topics and also include models for **reduction of road danger** and **better access to living areas** for all.
EXTERNAL LINKS	• Traffic Flow Prediction (ScienceDirect) • Performance of Prediction Algorithms for Modelling Outdoor Air Pollution Spatial Surfaces (ACS Publications, Environmental, Science & Technology) • Advances in air quality modelling and forecasting (ScienceDirect) • Data-Driven Framework for Understanding and Predicting Air Quality in Urban Areas (Frontiers in Big Data) • Sustainable Traffic and Transport (TNO)

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Predictive Modelling	
PRE-CONDITIONS & ENABLING CONDITIONS	***Technical:*** It is crucial that a prediction system automatically receives loop detector data, based on which prediction models can be trained. Since new data is continuously received, this requires a system which can handle large amounts of data.
CONSTRAINTS/ BARRIERS for implementation	***Technical:*** Depending on the size of the road network, it may be necessary to select a smaller sub-area for predictions. For example, it may not be feasible to generate predictions for all road links in a city based on one model. Graph neural networks may be suitable to consider predictions at network-scale in the future, but current developments in academia are limited to relatively small sub-networks.
INSTRUMENTS/ Processes for implementation	• Integrated land use and urban planning with energy and climate https://netzerocities.app/resource-1678 • Integrated land use planning and urban space management with mobility planning https://netzerocities.app/resource-1688 • Mobility Management https://netzerocities.app/resource-1768
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	Large-scale prediction systems can provide insights and decision support to e.g. traffic managers. New developments in explainable AI have the potential to provide additional information and explanations to users of the system, but in practice it remains challenging to ensure that these 'explanations' are sufficiently actionable.
IMPACTS (Indicators & DNSH)	Emissions, Energy consumption, Cost

3.7.2 Digital Twin (Built environment)

- Authors: **VTT**
- Knowledge Repository link: **https://netzerocities.app/resource-1965**

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the "orange" fields of this solution, and then it has been afterwards reviewed by JRC and completed the "pink" fields, and the Knowledge Repository content has been updated with JRC's input. So, here only the "orange" fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

Digital Twin (Built environment)
The **BIM based Digital Twin** as an approach enables and facilitates the following tasks: • optimized design and accurate **energy performance predictions** in the frame of **building renovation** and new building design projects, • **advancing real-time operations** for building energy management at a higher intelligence level, by employing data intelligence-driven optimization algorithms for increasing energy efficiency, maximizing self-consumption and improving predictive maintenance of building assets, • enabling the delivery of **human-centric energy management services** that put building occupants at the centre of decision-making and enable the definition of optimal energy management strategies without compromising of their comfort or well-being, • increasing the **data reach of urban planners**, advancing their intelligence and incorporating knowledge and insights to facilitate accurate target setting and informed guidance on green investments on the city authorities' side. There exist various developments (applications and tools leveraging Digital Twin approach to support energy efficiency and green transition) resulted from **EU R&D projects**, e.g.: SPHERE (https://sphere-project.eu/), Stardust (https://stardustproject.eu/smart-cities-network/), BEYOND (https://beyond-h2020.eu/),

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Digital Twin (Built environment)	
	MATRYCS (https://matrycs.eu/), SYNERGY (https://www.synergyh2020.eu/), and many others as well as commercial products, e.g. BuildingSmart (https://buildingsmart.fi/en/home/).
CO-BENEFITS	Based on the output from the various EU projects: Technology is able to equip various stakeholders such as facility managers, ESCOs, city decision makers, etc. with real-time energy performance analytics towards optimizing energy management, optimizing predictive maintenance of building assets, **supporting urban planning** and **setting/monitoring energy efficiency targets**, hereby **reducing GHG emissions**, **reducing energy needs** and **improving air quality**.
EXTERNAL LINKS	EU R&D projects: • SPHERE https://sphere-project.eu/ • Stardust https://stardustproject.eu/smart-cities-network/ • BEYOND https://beyond-h2020.eu/ • MATRYCS https://matrycs.eu/ • SYNERGY https://www.synergyh2020.eu/ Papers: • Digital Twins for the built environment (IET: The Institution of Engineering and Technology) • Digital Twin Definition for Buildings White Paper Released (SPHERE project)

3.7.3 Local Digital Twin (Planning/ Decision Making, cross-cutting)

- Authors: **OASC, TNO**
- Knowledge Repository link: **https://netzerocities.app/resource-1975**

Local Digital Twin (Planning/ Decision Making, cross-cutting)
The concept of **digital twins** traces its origins to product development and simulations of the behaviour of physical objects. It emerged from manufacturing and prototyping such as those conducted by NASA and Formula One racing cars. The digital object that forms the twin looks the same and behaves the same as the "real" object, and so the digital twin can provide **simulations and predictions**. The application of digital twins not only provides accurate **representation of complex objects** but also **enables interaction between them**. We can examine how the digital twin of an object bears relevance to the digital twinning of the **environment** in which it operates and investigate the impact and influences of the contextual environment on the object. So, digital representations of different aspects of the city can be built that can be linked together to provide key insights on new proposals for the city.

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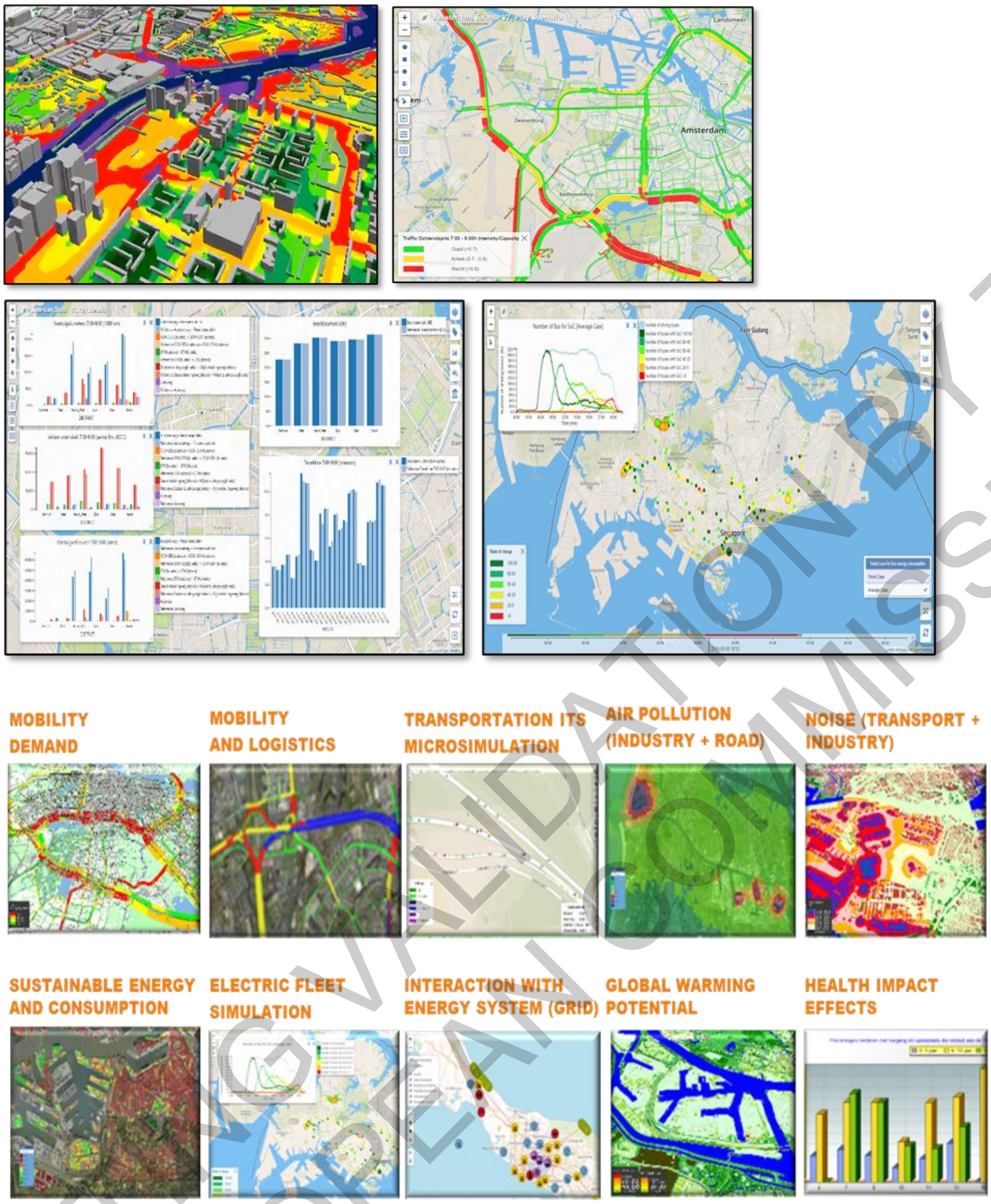
Local Digital Twin (Planning/ Decision Making, cross-cutting)



Examples of different ways to simulate and measure impact with Urban Strategy (TNO)

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Local Digital Twin (Planning/ Decision Making, cross-cutting)

The Digital Twin in Tianjin Ecocity, China

The **Living-in.EU** initiative defines local digital twins as: *a virtual representation of a city's physical assets, using data, data analytics and machine learning to help stimulation models that can be updated and changed (real-time) as their physical equivalents change*.

A **local digital twin** allows the simulation of plans before implementing them, exposing problems before they become a reality. A local digital twin can e.g. allow policymakers to simulate multiple 'what if scenarios' in a scenario-based analysis. In this way, it is possible to **find the best strategies to achieve a specific goal** in a short amount of time, or strategies that have similar effects while minimizing budget and resource usage.

The digital twin can also **provide real-time monitoring and proactive control** and **predictive maintenance** by data analytics, enabling cost and downtime reduction, along with many other benefits. For a city, a local digital twin representation should contain three pillars; data, simulation models (i.e. analytics) and modes to visualize the results and interact with them. A local digital twin integrates all these aspects in a single framework allowing a much more effective performance to city planning as it allows to provide an accurate representation of how any proposed changes will look and what the impact of any changes are. For example, the effects of road closures on noise and air quality. Therefore, making the decision-making process also more accessible e.g. between **local communities and stakeholders** to provide informed discussions on any new proposals.

When moving towards net zero, a city may have many kinds of **cross domain problems**, such as the need to balance the impacts of embedded carbon with the potential future energy savings involved in replacing old buildings with new and more energy efficient ones. To solve these, the digital twin systems in various domains should be designed scalable and future-proof as it is expected that over time more domains, more simulation models and more data will be added.

CO-BENEFITS	Through the use of digital twins, potential solutions to **city challenges** can be identified quickly and different solutions can be compared, **without the need to expend resources on building pilots or trials**.
EXTERNAL LINKS	• Living-in.EU, The European way of digital transformation in cities and communities: https://living-in.eu/
EXAMPLES	• DUET Digital Urban Twins: https://www.digitalurbantwins.com/ • Move 21: Multimodal and Interconnected Hubs for Freight and Passenger Transport Contributing to a Zero Emission 21st Century Main Home - Move21

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Local Digital Twin (Planning/ Decision Making, cross-cutting)	
PRE-CONDITIONS & ENABLING CONDITIONS	***Technical*** The city in question who would like a local digital twin solution should have some specific or dedicated datasets about their city which allows for a digital twin to be designed appropriately. The digital maturity of a city determines how well a local digital twin solution can be adopted. The more digitisation and data-driven decision making is embedded, the more likely digital twin solutions will provide added value to the decision-making process. ***Project*** Depending on the strategic, tactical and operational objectives of a city a local digital twin can be used for different reasons. Determining your objective beforehand is an important step to achieve the most value out of your local digital twin solution. For example, via an assessment tool a city can be assisted in finding their digitization needs and the right KPIs which can then be aligned with the use of local digital twins.
CONSTRAINTS/ BARRIERS for implementation	A major bottleneck for meaning digital twins are centrally collected locating data as input for a digital twin. This will result in non-scalable and non-futureproof digital twin solutions. A key property of futureproof digital twin framework should rather have a more distributed approach allowing for more interconnectivity and use of more data. **Data quality** determines for a large majority the quality of your model output for scenario-based analysis and data analytics. **Limited use of unified standards** results in a lack of common vocabulary, architectures, security and interoperability aspects. **Decision making**; the challenge of understanding monitoring of events vs foreseeing events and its impact. It is still a challenge to understand what the impact digital twin techniques can be when decisions are made on prepared against simulated scenario's. Limited emergence and exchange of best practices results in diverging approaches to assess quality of digital twins. A closed proprietary environment, as currently mostly available, is one of the major thresholds for acceptance by end-users Privacy and security issues or lack of compliance to laws and regulations for example to data inhibit the use of high quality data that is necessary input for digital twins.
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	Constant updates via appropriate automated techniques are technical challenges in itself as there needs to be an assessment which part of the digital twin should be given an update e.g. a new set of data and how to important these new updates into existing DTs. Limited implementation of self-learning (AI-assisted) or predictive modelling will not leverage the full potential of Digital Twins for long-term decision-making. An advantage of scenario-based analysis is that stakeholders can evaluate multiple what-if scenarios in a short time span. However, the more complicated a scenario, the more demand it will take on the available infrastructure. Besides computational power, it is therefore important to think ahead and design digital twins that are scalable and futureproof in terms of connectivity and useful data.
IMPACTS (Indicators & DNSH)	Energy consumption, Traffic flow prediction, Air & Noise pollution impact

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Local Digital Twin (Planning/ Decision Making, cross-cutting)	
Additional information from CASE STUDIES	• Living-in.EU, The European way of digital transformation in cities and communities: https://living-in.eu/ • DUET Digital Urban Twins: https://www.digitalurbantwins.com/ • Societal impact for accessibility and liveability | TNO

3.7.4 Scenario-based analysis (Mobility & Energy – One Model)

- Authors: **TNO**
- Knowledge Repository link: **https://netzerocities.app/resource-1985**

Scenario-based analysis (mobility & energy – one model)	
Decision making in the urban environment is typically performed using a **scenario-based analysis**. Stakeholders define a base scenario, which serves as the current situation in a city. Additionally, a **reference scenario** in which e.g. a road is closed can be defined to study the effects of the closure and make a comparison with the base scenario.  *Source: TNO* For a **scenario-based analysis** in a **city** it is required that **multiple domains are covered**, such as traffic, air quality, noise and energy. This enables a **multi-disciplinary analysis** in which the effects of interventions in one domain (e.g. traffic) on another domain (e.g. power consumption for charging) can be studied. A scenario-based analysis could also be performed in **multiple domains simultaneously**. Additionally, multiple parties could **collaborate** in one single platform when evaluating spatial plans, such as municipalities, provinces, consultancy companies and housing organizations.	
CO-BENEFITS	Scenario based analysis would allow to investigate what-if scenarios on various aspects of the urban environment. This includes measures that **enhance the attractiveness of the cities**, **improve air quality** or **reduce energy needs** and noise levels. Interactive models and tools can calculate various KPIs on these topics and also include models for **reduction of road danger** and **better access to living areas** for all.
EXTERNAL LINKS	• Sustainable traffic and transport (TNO) • Scenario Analysis (ScienceDirect)

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Scenario-based analysis (mobility & energy – one model)	
PRE-CONDITIONS & ENABLING CONDITIONS	***Technical:*** A key challenge in the development of a system for scenario-based analysis is the integration of models from multiple domains. For example, detailed models are needed for indicators such as traffic, air and noise. Typically, these models are maintained by separate entities, each having their own data format. It is required to bring these models together in a single framework before scenario-based analysis can be performed.
CONSTRAINTS/ BARRIERS for implementation	The key barrier for implementation is the significant computation time of models, which can take hours. To ensure that a scenario-based analysis can be performed quickly, it is expected that computations need to be paralyzed.
INSTRUMENTS/ Processes for implementation	• Integrated land use and urban planning with energy and climate https://netzerocities.app/resource-1678 • Integrated land use planning and urban space management with mobility planning https://netzerocities.app/resource-1688 • Mobility Management https://netzerocities.app/resource-1768
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	An advantage of scenario-based analysis is that stakeholders can evaluate what-if scenarios. However, it may still be required to compute the outcomes of many what-if scenarios before policy decision can be made. Even if evaluation of one what-if scenario is fast, it may still take a long time to evaluate and compare many scenarios.
IMPACTS (Indicators & DNSH)	Emissions, Energy consumption, Cost

3.7.5 Artificial Intelligence (AI) applications to climate neutrality

- Authors: **AIT**
- Knowledge Repository link: **https://netzerocities.app/resource-1999**

Artificial Intelligence (AI) applications to climate neutrality
Artificial Intelligence (AI) combines computer science and robust datasets to enable problem-solving by teaching algorithms to perform defined tasks. There are a range of AI applications that can contribute to climate neutrality in cities, across various themes, including energy, transport and built environment for example by: • Integrating and optimizing smart urban transport systems via mobility-as-a-service (MaaS) or other single on-demand mobility services; • Optimizing energy production and consumption via home technologies with a focus on energy saving and behaviour change; • Monitoring changes in the natural and the built environment via remote sensing with autonomous drones—used for multiple-object detection and tracking in aerial videos; One of the most difficult to assess aspects of urban performance has traditionally been the wind flow around buildings, whether that is thought of as an indicator of pedestrian comfort and safety, natural ventilation or pollution concentration and hence urban climate and energy consumption.

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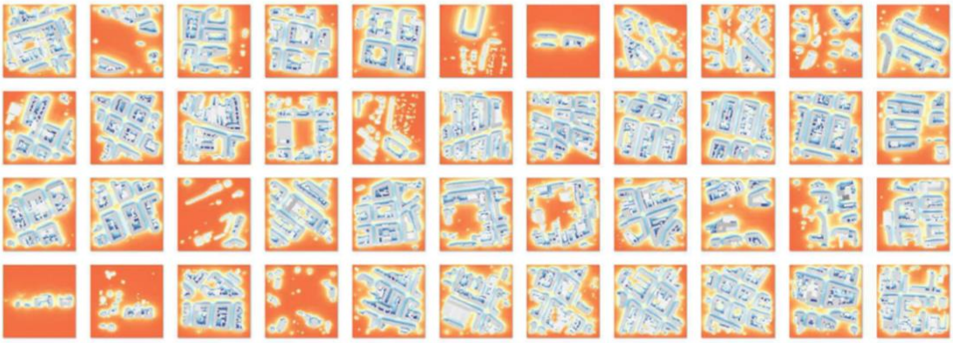
<table>
<tr><th colspan="2">Artificial Intelligence (AI) applications to climate neutrality</th></tr>
<tr><td colspan="2">
Wind Flow Prediction through Machine Learning, City intelligence Lab

Using AI, we can bring the world of CFD and wind flow assessment into the realm of iterative evaluation and optimization of design and equally important, can allow us to conduct even more complex studies of urban performance such as thermal comfort and energy consumption due to existing urban climate environments.</td></tr>
<tr><td>CO-BENEFITS</td><td>Reduce risk to natural and climate hazards,
Enhance stability of the urban infrastructure,
Reduce energy needs,
Reduce hot spots/urban heat islands in the city,
Enhance attractiveness of the cities, Healthier and more attractive lifestyles</td></tr>
<tr><td>EXTERNAL LINKS</td><td>Wind Flow Prediction through Machine Learning, City intelligence Lab</td></tr>
</table>

<table>
<tr><th colspan="2">Artificial Intelligence (AI) applications to climate neutrality</th></tr>
<tr><td>PRE-CONDITIONS & ENABLING CONDITIONS</td><td>Political:
The AI development must be politically independent in order not to follow individual interests, but to show an accurate outcome. a solid legal base should be therefore installed, and the development process monitored.

Economic:
Similar to political interests, the impact of economic interests must be avoided at any time when developing an AI for the public good and its independency ensured.

Social:
An accurate representation (data sets) of social properties within the population, leaving no one behind, must be existing to provide outcome that takes social questions also into account

Technical:
A digital baseline of a city, such as a 3D Model or digital twin, is needed as representation of its current condition of the environment the AI will be implemented in. such 3D model can be then used for instance, to model the climatic situation (UV, wind) of a city using AI and to predict their impact on future planned developments.</td></tr>
<tr><td>CONSTRAINTS/ BARRIERS for implementation</td><td>Political: political influences guided by individual interests
Economic: economic influences guided by individual interests
Social: involvement of existing social structures within the urban fabric can have an impact on AI planning methods due to challenges of their incorporation into an AI model
Technical: existence and level of accuracy of existing data and 3D representation</td></tr>
<tr><td>INSTRUMENTS/ Processes for implementation</td><td>Training,
Awareness Campaigns</td></tr>
</table>

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Artificial Intelligence (AI) applications to climate neutrality	
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	The development of computer vision has provided the means of estimating population count and socio-economic conditions using remote sensing and GIS technology. This can be especially useful in contexts of very limited data and the absence of global data collection strategies [1]. Population mapping is possible using new forms of data such as telecommunication data, credit card data and social media for real-time population estimation. The interactions between individuals and communities as well as their mobility behaviour can also be inferred. Information can be retrieved in order to identify meaningful neighbourhoods. Population mapping initiatives can be leveraged by AI techniques to evaluate the state of economic and spatial inequalities at the urban scale. AI methods can be adapted to include non-residents in the analysis of city behaviour for better planning. In particular, outside commuters or tourists can be included to provide richer information on the city. Population data are very often of a sensitive nature, carrying out population assessment for the benefit of urban planning is not risk-free (marginalisation, discrimination). [1]. Y. Xie, A. Weng and Q. Weng, "Population Estimation of Urban Residential Communities Using Remotely Sensed Morphologic Data," in IEEE Geoscience and Remote Sensing Letters, vol. 12, no. 5, pp. 1111-1115, May 2015, doi: 10.1109/LGRS.2014.2385597.
IMPACTS (Indicators & DNSH)	Reduction of CO_2 emissions compared to traditional vehicles (trucks, vans), [g/tonne km] , Change in noise level [dB]), Energy generation (UV potential MWh, Cooling of urban places (Shading) (degree Celsius)
Additional information from CASE STUDIES	• Masterplanning Norway; https://cities.ait.ac.at/site/index.php/2020/04/15/master-planning-norway/) • Urban renewal Uzbekistan; https://cities.ait.ac.at/site/index.php/2019/09/20/data-augmented-urban-renewal-in-uzbekistan/ • Singapore; https://cities.ait.ac.at/site/index.php/2018/08/21/interactive-web-mapping/

3.7.6 GHG Monitoring from Space

- Authors: **OASC, VTT**
- Knowledge Repository link: **https://netzerocities.app/resource-2013**

GHG Monitoring from Space
Greenhouse gas (GHG) monitoring from space is a solution that uses **satellites to measure** carbon dioxide (CO2), methane (CH4), nitrous oxide (N20) and ozone (O3) **emissions in the atmosphere**. Construction industry produces a significant portion of global GHG emissions, and buildings with their energy sources are one of largest contributors to these emissions. The technology allows to **track the sources and movement of emissions**.

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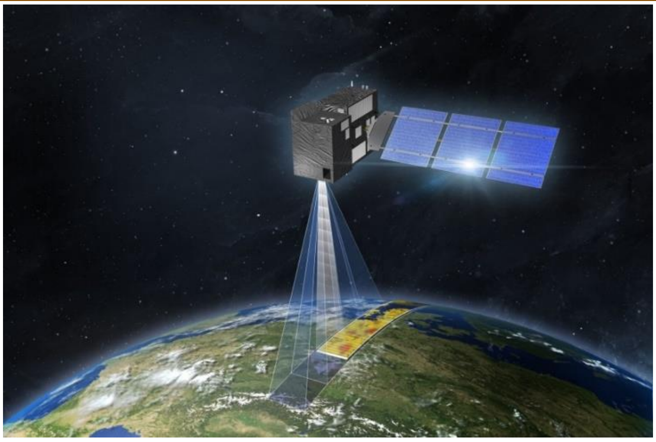
GHG Monitoring from Space



Carbon dioxide monitoring satellite (Source: ESA https://www.esa.int).

The benefits of space monitoring are numerous. For the context of climate change, the solution helps to better understand how **human activities are contributing to the GHG emissions**, and how the actions can reduce them to slow down global warming. By providing a global view of emissions, **cities** together with policymakers and businesses can make **informed decisions** on reducing emissions and mitigating climate change. This technology helps to monitor compliance with emissions reduction agreements and supports the development of **new policies and regulations** promoting sustainability. In addition, GHG monitoring from space enables **identifying high levels of emissions**, that may be produced by industry, cities or incidents like natural disasters or accidents. To sum up, this solution has the potential to play a key role in **mitigating to climate change and promoting sustainability**.

Methane flow data indicating locations (Source: Kayrros https://www.kayrros.com)

CO-BENEFITS	GHG monitoring from satellites provides reliable evidence on **GHG emissions** that a city can utilize in developing **decarbonisation strategy and planning** through **regulations and policies** that reduce **GHG emissions** and promote **climate mitigation**.
KEYWORDS	Technology, Climate resilience, GHG, Governance and Policy
EXTERNAL LINKS	GEO, ClimateTRACE, WGIC (2021). GHG Monitoring from Space: A mapping of capabilities across public, private, and hybrid satellite missions. European Space Agency (ESA), web site. Kayrros company, web site.
EXAMPLES	Cities have an important role in cutting GHG emissions globally, especially in limiting global warming that is almost 1.5°C above the pre-industrial levels. Some companies provide GHG emissions data tools for cities. CDP web site lists some of these in link.

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GHG Monitoring from Space	
PRE-CONDITIONS & ENABLING CONDITIONS	***Political:*** Political consensus to make decisions ***Economic:*** Funding for climate mitigation and sustainability. ***Technical:*** City level capabilities to take solutions into action.
CONSTRAINTS/ BARRIERS for implementation	***Political:*** Policymakers with different ambitions. ***Economic:*** Different objectives in businesses. ***Technical:*** Status of digitalization varies in different cities.
INSTRUMENTS/ Processes for implementation	• Capacity building training https://netzerocities.app/resource-1578 • Educational/ Capacity building barriers identification https://netzerocities.app/resource-1588 • Monitoring systems: https://netzerocities.app/resource-1418 • CO2 emission platforms: https://netzerocities.app/resource-1418 • City dashboards: https://netzerocities.app/resource-2065 • Vulnerability and risk information systems https://netzerocities.app/resource-2115 • Satellite and Geospatial Data https://netzerocities.app/resource-2125
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	The GHG emissions are affected by many issues and local work by a city alone may not change circumstances globally.
IMPACTS (Indicators & DNSH)	Enhance GHG emissions reduction from cities through observations (carbon dioxide (CO2), methane (CH4), nitrous oxide (N20) and ozone (O3).
	No risks.

3.7.7 BIM and CIM (Building/Civil Information Model)

- Authors: **OASC, VTT**
- Knowledge Repository link: **https://netzerocities.app/resource-2023**

BIM / CIM
Building Information Model (BIM) and **Civil Information Model (CIM)** are digital tools transforming the construction industry. BIM is a set of technologies, processes, and policies of creating and managing digital representations of a building or structure, while CIM is focused on civil infrastructure facilities and sometimes called infraBIM. These tools enable stakeholders to design, construct and operate projects in city environment more efficiently. These tools help to manage life cycle of various projects effectively. The approach with BIM and CIM provides a comprehensive understanding to architects, engineers, and contractors to **collaborate** efficiently, reduce errors, and streamline construction process (Kumar, 2016 and Chang et al., 2016). Moreover, digitalisation enables **repositories for data storage and analysis,** for example to provide insights for project **management, risk mitigation, and decision-making**.

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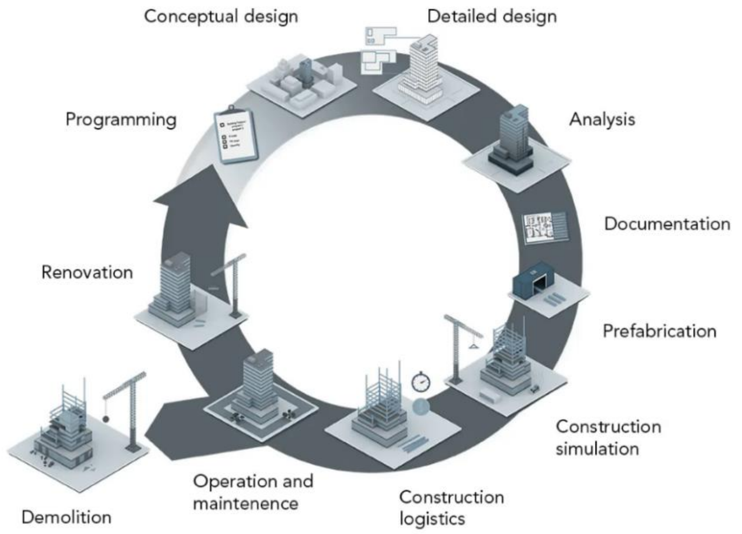
BIM / CIM



Life cycle for BIM (Source: Buildext).

Connection of BIM and CIM in city (Source: Accasoftware).

The use of BIM and CIM is currently becoming increasingly popular in many countries. They offer numerous benefits, including **increased efficiency and productivity, reduced waste, improved communication and collaboration, enhanced safety, and more accurate cost estimating and scheduling**. For construction industry, these technologies offer opportunities to develop built environments that have reduced environmental impacts. By this way cities may be built and managed from buildings to roads, bridges, and other infrastructures that are more **sustainable and resilient**.

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BIM / CIM	
Modeling benefits in city (Source: Geospatialworld)	
CO-BENEFITS	BIM and CIM improve **land use management** in cities through designing a built environment that **reduce energy needs** and provide **better access to living areas for all**.
KEYWORDS	Technology, BIM, CIM, Building information, Civil information, Collaboration, Governance and Policy
EXTERNAL LINKS	Kumar, 2016: Book "A Practical Guide to Adopting BIM in Construction Projects" (Whittles Publishing). Cheng et al, 2016 : Article on "Analytical review and evaluation of civil information modelling" (Automation in Construction Vol. 67, July 2016, p.31-47). Buildext, web site 2023 Accasoftware, web site 2022 Geospatialworld, website 2019. Article on "role of BIM in Urban Construction" by Jadlav.
EXAMPLES	For BIM and CIM, the maturity of use varies in different countries varies. There are countries in higher level with national documentation and strategies, and countries where modelling is in lower level and strategies are being developed. Project examples: • Finland: The “Mall of Tripla“ by 2021 is a commercial project covering 355,000 m². The “West metro“ by 2020 is a 21km metro network. • - UK: “Crossrail“ is a 118km railway line with 38 stations crossing London partially underground.

BIM / CIM	
PRE-CONDITIONS & ENABLING CONDITIONS	***Political:*** Political interest to digitalize construction industry. ***Economic:*** Funding for built environment development. ***Social:*** Citizens with interest to participate in public hearings. ***Technical:*** Capabilities of project stakeholders to utilize BIM/CIM. ***Legal:*** Regulations guiding industry towards digitalization.
CONSTRAINTS/ BARRIERS for implementation	***Political:*** Policymakers with different ambitions. ***Economic:*** Investments to regulatory and policy changes not happening. ***Social:*** Citizens with lack of interest on digitalization. ***Technical:*** Status of digitalization varies. ***Legal:*** Regulatory and policy changes take time.

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BIM / CIM	
INSTRUMENTS/ Processes for implementation	• Capacity building training https://netzerocities.app/resource-1578 • Educational/ Capacity building barriers identification https://netzerocities.app/resource-1588 • Digital Twin (Built environment) https://netzerocities.app/resource-1965 • Local Digital Twin (Planning / Decision Making, cross-cutting) https://netzerocities.app/resource-1975 • Applying Open Standards https://netzerocities.app/resource-2203 • Data Strategy / Governance https://netzerocities.app/resource-2149
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	Companies in industry have different technical maturity. It takes time and effort to have national industry-wide transition to BIM/CIM solutions. The education and skills update in main preconditions for the BIM/CIM wide use.
IMPACTS (Indicators & DNSH)	Adoption of BIM/CIM solutions in projects (Estimation per country e.g. percentage)
	No risks.

3.7.8 Platform Architecture

- Authors: **OASC, TNO**
- Knowledge Repository link: **https://netzerocities.app/resource-2033**

Platform Architecture
City Platforms are a key part of any city architecture and cities and communities will each have a variety of different platforms at different layers of their overall city platform. The logic behind the use of platforms is straightforward – instead of using many separate applications containing duplicating functionally, **all common functionalities** can be **collected into a platform** and solutions which are built on top of that platform then only need to possess unique functionality. The platform simplifies the use of its platform components and ensures interaction between them. Thus, the platform frees up resources to focus on solving unique problems. The planning of new solutions can be coordinated within the scope of the platform to minimize duplication of efforts in solving the same problems. New solutions can be gradually included in the platform for widespread use. All interactions between the platform and applications can use standardized interfaces (**API methodology**). Any city will have many, many existing platforms used by different organizations or departments and with various types of functions. They may be **horizontal platforms** such as IoT platforms, data platforms, AI platforms, etc., or they may be **platforms focused on delivering a specific set of services** such as smart mobility platforms, energy management platforms and so on. The key challenge is that these platforms are often built within silos, and it can be very difficult to share and manage data between them.

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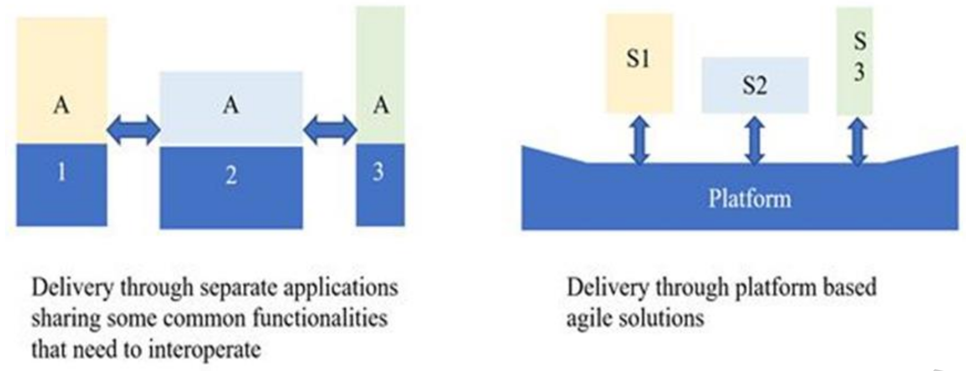
Platform Architecture



A **city platform architecture** does not consist of a massively complex set of software and hardware but rather a **federation of many city platforms that work together seamlessly to help manage the city services in a holistic and effective way**. Cities and communities will not need to develop such a platform all at once but rather can use the opportunity of new smart initiatives to develop the relevant parts of that platform in a modular fashion. What is important is that each platform that is developed to meet the needs of a specific initiative is also designed to fit within an overall common framework so that it can become an integral part of the developing smart city platform.

In short in order **to build a city platform, the city needs to**:
- Integrate existing platforms so that they can work well together;
- Make sure that new platforms developed to meet some specific priorities are built in a modular way to enable these new platforms to build towards the overall comprehensive smart city platform.

To do this, they need to put in place a platform architecture that can act as a **blueprint for the work of integration**.

CO-BENEFITS	By designing a city platform that is futureproof and scalable, more digital solutions can be integrated and utilized to assist cities in finding novel insights for example through a digital twin solution on a city platform.
EXTERNAL LINKS	• Urban Data Platform | Living in EU (living-in.eu)

Platform Architecture	
PRE-CONDITIONS & ENABLING CONDITIONS	Further extensions in City Platforms are foreseen in applying open standards and open link data for linking with third party solutions, scalable digital solutions and data collection and sharing. Thus, interoperability is a prerequisite for a scalable City Platform. Designing a futureproof and scalable city platform will allow the possibility to enable more (inter)connectivity and use of data for example with additional data sources or on how to connect data, visualisations and models into an integrated digital twin framework.
CONSTRAINTS/ BARRIERS for implementation	Lack of harmonization in (Open) standards allows less computability between data and applications from third parties with the city platform. Every city has its own approach to digitization resulting in different digital design/architecture of the city's digital platforms. An approach that is not modular inhibits collaboration with other types of interfaces from other systems and frameworks of other city departments or third parties. As a consequence, it is more difficult to for example prefilter towards future convergence scenarios of digital twins in a city platform.

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Platform Architecture	
	Absence of a solid data infrastructure with appropriate data organisation and standardisation inhibits the adoption of scalable digital solutions on the city platform. No suitable back-end city platform limits digital twin infrastructure that encompasses all necessary information to allow deployment of solutions for challenges in cross-cutting domains (e.g. energy & mobility) in terms of data, visualisation and modelling. Ideally, the back end could subsequently be used to derive different front-end representations for different users depending on the way for example the digital twin is being used. A key design approach is that no data is hold centrally. Instead connected modules hold the relevant data locally in memory.
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	A lack of integration which ensures that for example simulation models and data visualization interfaces can effectively interact and exchange data in a dynamic manner. This also limits the possibilities to reduce computation time of predictive modelling. Lack of uptake of standards for designing, modelling and implementing digital solutions in a scalable fashion.
IMPACTS (DNSH)	• Results | digital urban European twins (digitalurbantwins.com) • Learn - Move21 - Download free Assets • Living-in.EU, The European way of digital transformation in cities and communities: https://living-in.eu/ • DUET Digital Urban Twins: https://www.digitalurbantwins.com/ • Societal impact for accessibility and liveability | TNO

3.7.9 CO2 Emission Trading Platforms

- Authors: **OASC, VTT**
- Knowledge Repository link: **https://netzerocities.app/resource-2047**

CO2 Emission Trading Platforms
There is a strong global interest on **reducing CO2 emissions**. Two cost-effective main routes for this are **emissions trading** and carbon taxes. CO2 trading platforms are digital marketplaces where businesses, governments, and individuals can **buy and sell carbon allowances**. It may include one or more exchanges, brokerage, and auctions for allowances. Services may be provided by private sector or government agencies. Actors purchase credits either for compliance (targets) or voluntary purposes. Carbon credits represent the right to emit one tonne of carbon dioxide or its equivalent, traded on these platforms to help **meet emissions targets set by governments or international agreements** and reduce greenhouse gas emissions. CO2 trading platforms provide a useful **tool for reducing emissions** and creating a more **sustainable future**. By putting a price on carbon, these platforms promote the **transition to climate neutrality** by providing **economic incentives** for reducing emissions and support **investing in renewable energy and low-carbon technologies**. The global trading market was about 71 billion Euros in 2022 (Business Wire). Trading involves tradeable units that can take a form of **cap-and-trade system**, like the European Union's Emission Trading System (EU ETS). In EU ETS market establishes an emission price necessary to meet that cap.

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CO2 Emission Trading Platforms

Five trading platform developed by startus (Source: StartUs insights)

CO-BENEFITS	CO2 emission trading platforms have a great impact on **climate mitigation** and on globally **reducing GHG emissions**. For cities, this means better **health** through **improved air quality**. Companies have opportunities to contribute to **reduce carbon footprint**.
KEYWORDS	Technology, Platform, GHG, Business, Governance and Policy
EXTERNAL LINKS	• EU ETS, web site: https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets_en • Implementing Effective Emissions Trading Systems from IEA: https://www.iea.org/reports/implementing-effective-emissions-trading-systems • Businesswire, web site: https://www.businesswire.com • StartUsInsights.com, web site: https://www.startus-insights.com/innovators-guide/discover-5-top-carbon-trading-solutions-developed-by-startups/ • UN Carbon Offset Platform https://unfccc.int/climate-action/united-nations-carbon-offset-platform
EXAMPLES	There are globally numerous emission trading platforms available. Some of those include: Climate trade marketplace, South Pole marketplace, Carbon Trade Exchange, and Climate Impact X.

CO2 Emission Trading Platforms	
PRE-CONDITIONS & ENABLING CONDITIONS	***Political:*** Political support to reduce carbon emissions. ***Economic:*** Economic incentives for companies and individuals to reduce carbon emissions. ***Technical:*** Trading platforms are easily available. ***Legal:***

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CO2 Emission Trading Platforms	
	Regulations and policies are supporting active use of trading platforms as part of business.
CONSTRAINTS/ BARRIERS for implementation	***Political:*** Environmental values are not considered as important as financial savings. ***Economic:*** Money is considered more important than reduction of carbon emissions. ***Technical:*** Easy services where companies can do trading based on their strategy. ***Legal:*** Legislation not considering reduction of carbon emissions and use of carbon emission trading platforms.
INSTRUMENTS/ Processes for implementation	• Capacity building training https://netzerocities.app/resource-1578 • Educational/ Capacity building barriers identification https://netzerocities.app/resource-1588 • GHG Monitoring from Space https://netzerocities.app/resource-2013 • Artificial Intelligence (AI) applications to climate neutrality https://netzerocities.app/resource-1999
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	Market situation effects on opportunities for e.g. companies to reduce carbon emissions.
IMPACTS (Indicators & DNSH)	Carbon footprint (tonne of carbon dioxide)
	No risks.

3.7.10 City Dashboards

- Authors: **TNO**
- Knowledge Repository link: **https://netzerocities.app/resource-2065**

City Dashboards
City Dashboards are typically deployed by stakeholders such as **municipalities**, **provinces** or any other **organization** interested and involved **in urban planning**. Dashboards provide cities with **visual insights about various indicators** in their city environment, such as **air quality**, **emissions**, **traffic**, and **road safety**. These insights **can be generated in real-time**, based on different current, as well as historical, data that has been collected in the past. Examples of such data can be real-time sensor data which can be provided by IoT sensors owned by inhabitants or by a municipality, road authority, etc. (e.g., air quality sensors) and by sensors that are part of the road infrastructure, such as loop detectors that count traffic. Dashboards provide stakeholders with **clear visual support**, in the decision-making processes for steering towards their climate neutrality goals, and can be used as a **quick**, **clear** and **tangible tool** to provide a good overview of the KPIs of interest in a city. They enable the various **stakeholders** to quickly **inspect** the current situation in a city and use these insights during the urban planning process. For example, energy companies and power grid operators may be interested in KPIs related to e.g., demand for electric vehicle charging. Further, emissions can indicate critical parts of the network that require attention, while potential improvements after implementation of specific measures can be monitored easily. Individual **KPIs**, if desired, can be presented in **different forms**, such as tables, charts, graphs, text etc., other than maps. In addition to visualization of KPIs, a dashboard can also show in which areas only a few sensors are installed, which means that it can indicate in which areas it may be beneficial to deploy additional sensors to get a better overview and monitoring of the city.

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City Dashboards

Dashboards can assist stakeholders in several domains, which can result in a better living environment of citizens. On top of that, via citizen participation actions, citizens can be involved in getting awareness of their city conditions, as well as in participating in the decision-making processes.

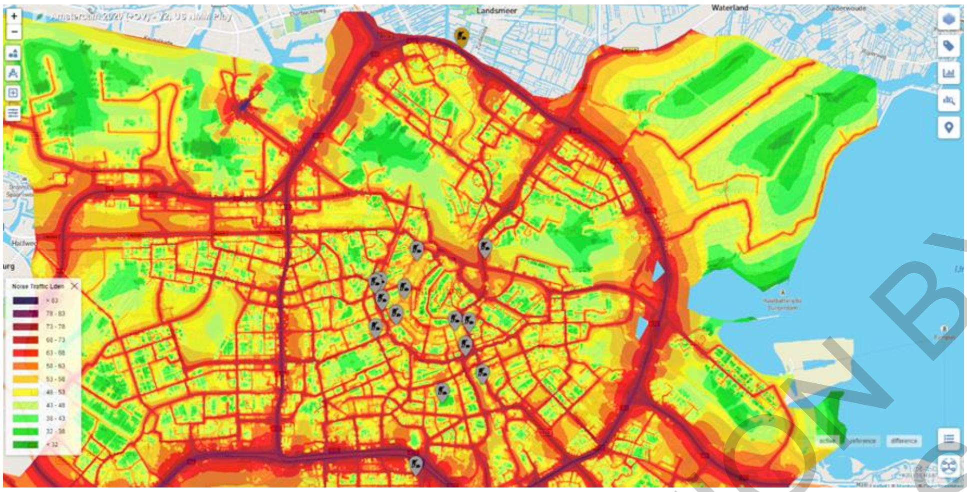

Figure 1: Inspecting noise levels in Amsterdam using a dashboard (source: TNO)

CO-BENEFITS	City dashboards allow to investigate measures that **enhance the attractiveness of the cities**, **improve air quality** or **reduce noise levels**. Interactive models and tools can calculate various KPIs on these topics and include models for **reduction of road danger** and **better access to living areas** for all.
KEYWORDS	Direct connections to **technical solutions**: • Predictive modelling • Digital Twin (Built environment) • Local Digital Twin (Planning / Decision Making, cross-cutting) • Scenario-based analysis (Mobility & Energy - One Model) • Platform Architecture Direct connections to **Instruments**: • Integrated land use and urban planning with energy and climate • Integrated land use planning and urban space management with mobility planning • Sustainable Urban Mobility Plan (SUMP)
EXTERNAL LINKS	• Building City Dashboards for Different Types of Users (Journal of Urban Technology) • Sustainable traffic and transport (TNO)
EXAMPLES	• Urban Strategy - TNO - YouTube

City Dashboards	
PRE-CONDITIONS & ENABLING CONDITIONS	***Technical and governance***: There should be an IT infrastructure which continuously collects data from various parties. This means that there should be one organization that is responsible for collecting the data and maintaining the system. ***Political/Legal/Regulation***: Besides the IT infrastructure, there should be an entity within e.g., a municipality which maintains the city dashboard. Typically, this is a mobility department which maintains traffic models and collects building data. Furthermore, such a department can collaborate with external organizations such as knowledge institutions and data providers to include more functionalities. For example, for displaying indicators on

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City Dashboards	
	safety (e.g., incident data) it may be necessary to collaborate with a road safety institute. Existing data policies for data sharing and protection could be needed (link to Data Strategy and Governance). ***Funding and financing:*** Funding for developing such a system can be realized through internal budgets of a municipality, as well as participation in e.g. European projects.
CONSTRAINTS/ BARRIERS for implementation	***Technical:*** Visualization of privacy sensitive data is typically challenging. For example, getting detailed insights on traffic accidents requires accident data, but typically this data is aggregated to prevent that individuals in a dataset can be identified. Similar challenges arise in the context of Mobility-as-a-Service. Getting detailed insights on travel behavior requires information about individual trips, but service providers may not be allowed to share data which describes individual trips. There are multiple solution directions that can be explored to deal with privacy sensitive data. First, multiple parties may enter a consortium in which contracts are established describing how data may be used. Second, it may be possible to pre-process existing data such that data belonging to individuals cannot be identified in the resulting dataset. Finally, new machine learning techniques such as federated learning may be used to extract insights from multiple separate datasets, without revealing the original data. ***Funding and financing***: Initiation of a project normally by the municipality or other stakeholder who owns the data and requires the dashboard from an expert who could be a research institute, a university, a consultancy, etc. ***Social:*** In the LocalRES project citizens were not comfortable with seeing data in maps, while others were comfortable. Citizen workshops made very clear that community supporting tools need to be adapted both to the specific requirements of the participating town as well as to the needs of the individual end users. The development of community tools needs to consider the varying degree of technical literacy [1]. Different options of visualization might be needed depending on the end-user (For experts-->maps, for citizens a possibility to visualize their data by searching by address instead of a map and showing big numbers with a narrative). [1] https://open-research-europe.ec.europa.eu/articles/2-129
INSTRUMENTS/ Processes for implementation	• https://netzerocities.app/resource-1678 • https://netzerocities.app/resource-1688 • https://netzerocities.app/resource-1708
IMPACTS (Indicators & DNSH)	Emissions, Energy consumption, Cost
Additional information from CASE STUDIES	• https://www.ams-institute.org/urban-data/urban-data-science/

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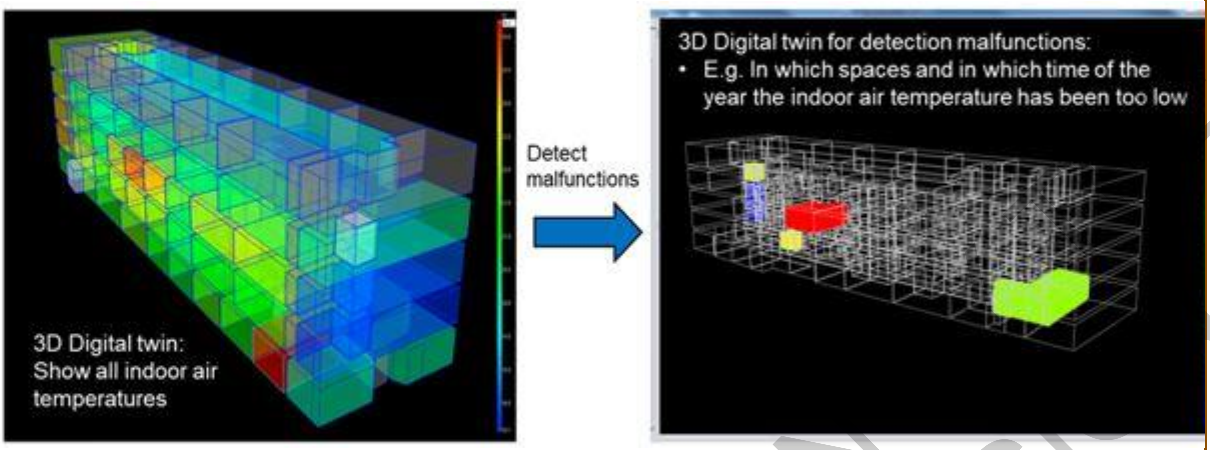
3.7.11 Predictive Maintenance supporting tools

- Authors: **VTT**
- Knowledge Repository link: **https://netzerocities.app/resource-2075**

This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

Predictive Maintenance supporting tools

The **Predictive Maintenance supporting tools** in general aim at the facilitating predictive maintenance tasks for various large **energy systems** (e.g. HVAC) installed in **buildings**.



Existing modern **real-time data-based solutions** are able to support recognizing **building technical systems' malfunctions**, inefficiencies and optimization possibilities. Continuous **data collection and data analytics** are enabled by installed **smart building infrastructures** (such BACS system and data cloud infrastructures) and **IoT technology**, in order to provide the quality predictive maintenance service with near real-time metering data and history data from studying facilities in the city.

In particular companies are active in this domain. There exist commercial products to support predictive maintenance tasks such as e.g. from Siemens MindSpere toolset or HippoCMMS. Such EU research projects as SYNERGY and BEYOND do advanced research in this area too, leveraging big data, AI and IoT.

CO-BENEFITS	The predictive maintenance support tools are able to equip buildings' owners, facility managers and ESCOs, with **real-time energy performance analytics** towards **optimizing energy management**, **maximizing self-consumption** and optimizing predictive maintenance of building assets, hereby **reducing GHG emissions** and **reducing energy needs.**

Predictive Maintenance supporting tools	
PRE-CONDITIONS & ENABLING CONDITIONS	***Technical:*** IoT, access to building energy performance data

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<table>
<tr><th colspan="2">Predictive Maintenance supporting tools</th></tr>
<tr><td>CONSTRAINTS/ BARRIERS for implementation</td><td>Social:
Governance and social innovation practices demand new management approaches that move away from command and control methods and that are built on convening power and soft leadership. Especially when relating to bottom-up initiatives, the traditional responsibilities, expertise and power dynamics have to be reconsidered and distributed in different ways.

Technical:
Availability of building energy performance data</td></tr>
<tr><td>INSTRUMENTS/ Processes for implementation</td><td>• Capacity building training https://netzerocities.app/resource-1578
• Educational/ Capacity building barriers identification https://netzerocities.app/resource-1588
• Digital Twin (Built environment) https://netzerocities.app/resource-1975
• BIM/ CIM https://netzerocities.app/resource-2023</td></tr>
<tr><td>DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation</td><td>If the BACS data is not sufficient, then maintenance action will not be based on correct information.</td></tr>
<tr><td rowspan="2">IMPACTS (Indicators & DNSH)</td><td>Better quality decision making to support predictive maintenance, resulted savings for costs and time</td></tr>
<tr><td>DNSH: no risks identified</td></tr>
<tr><td>Additional information from CASE STUDIES</td><td>Example of existing solution:
• Siemens Mindsphere</td></tr>
</table>

3.7.12 Advanced Renovation Support

- Authors: **VTT**
- Knowledge Repository link: **https://netzerocities.app/resource-2085**

Advanced Renovation Support

The **renovation supporting solutions** can potentially support users (Facility managers, Building owners, ESCOs) in the design and selection of **most appropriate building renovation actions**.

In modern data-driven developments, this is achieved by leveraging the **real-time data** coming from the **actual operation** of the building **combined with occupants' behaviour- and comfort profiles**. With the support of **data science** (i.e. AI algorithms) an **alternative renovation scenarios** for the selected buildings in the city can be studied. The alternative scenarios may include various use cases and examples of potential renovation actions and their comparison & ranking based on target emission measures, energy savings, costs and other parameters.

	Space heating and hot water		Appliance electricity		Space cooling		Carbon footprint		Energy cost	Investment	Payback time
CASE 1	kWh/a	kWh/m2,a	kWh/a	kWh/m2,a	kWh/a	kWh/m2,a	tCO2/a	kgCO2/m2,a	€/a	€	a(year)
Before	99894	50	89575	45	14329	7	70	0.04	23355	-	-
After	88912	44	89575	45	16692	8	67	0.03	22853	212784	423.9
Savings	10982	6	0	0	-2363	-1	3	0	502	-	-

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Advanced Renovation Support	
There the commercial products exist in the market such as e.g. IDA-ICE. From European research side, there are projects running that aim at developing AI/Data driven applications and tools to support renovation tasks, such as, for example BEYOND, SYNERGY or MATRYCS.	
CO-BENEFITS	Enhance the ability of urban energy planners, ESCOs, building managers, etc. to plan and implement **renovation in lower secure costs**. Facilitating implementation of renovation actions secures in turn **reducing GHG emissions**, improve buildings' **comfort** incl. air quality.
EXTERNAL LINKS	• Häkkinen. T., Ala-Juusela. M., Shemeikka, J. (2016). Usability of energy performance assessment tools for different use purposes with the focus on refurbishment projects. Energy and Buildings Volume 127, Pages 217-228. • Comprehensive study on buildings renovation (EC)

Advanced Renovation Support	
PRE-CONDITIONS & ENABLING CONDITIONS	***Technical:*** Availability of IoT and data APIs in buildings, static design information about building under renovation decision making ***Social:*** Communication support users (Facility managers, Building owners, ESCOs) in the design and selection of most appropriate building renovation actions while sharing the same information during process.
CONSTRAINTS/ BARRIERS for implementation	***Social:*** In LocalRES project citizens were not comfortable with seeing data in maps, while others were comfortable. Citizen workshops made very clear that community supporting tools need to be adapted both to the specific requirements of the participating town as well as to the needs of the individual end users. The development of community tools needs to consider the varying degree of technical literacy [1]. Different options of visualization might be needed depending on the end-user (For experts-->maps, for citizens a possibility to visualize their data by searching by address instead of a map and showing big numbers with a narrative). [1] LocalRES project
INSTRUMENTS/ Processes for implementation	• Capacity building training https://netzerocities.app/resource-1578 • Educational/ Capacity building barriers identification https://netzerocities.app/resource-1588 • Building Automation and Control Systems (BACS) https://netzerocities.app/resource-758
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	Lack of correct data for decision making can lead to unprecise facts for support. Both technical and social data collected from citizens need to be comprehensive.
IMPACTS (Indicators & DNSH)	Renovation planning and decision-making costs- and time- saving
	NO RISKS

3.7.13 Data and Solution Catalogues

- Authors: **OASC, AIT**
- Knowledge Repository link: **https://netzerocities.app/resource-2095**

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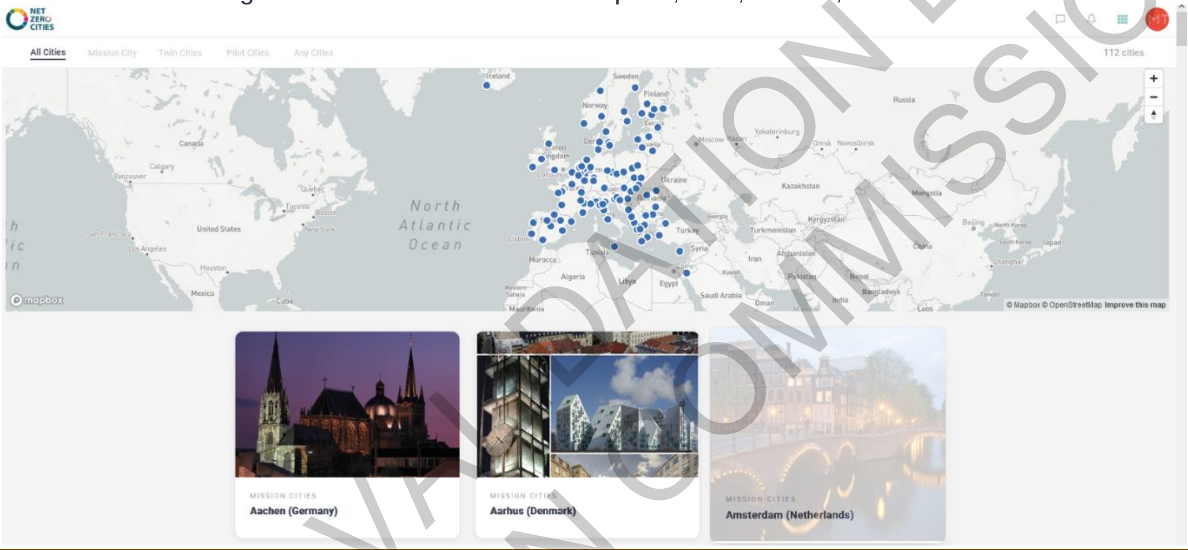
Data and Solution Catalogues

Given the exponentially increasing amount of data being generated in cities and communities by many different agencies and the fact that much of this data could be of value to other agencies, increasing numbers of **local data sharing ecosystems (Local Data Space)** are being set up, where many different agencies can make useful data that they are gathering available for use by other agencies. The aim is to make it easy for organizations to offer up their data and easy for potential users of that data to find and access that data.

This requires a **well-managed environment** where the data is managed in a way that ensures that it can only be used by pre-agreed agencies for pre-agreed purpose. One requirement of such an environment is a **data and solutions catalogue**, which provides **functionalities to publish and search for different data service offerings**.

Data offerings can be organized into **groups/categories** - in a **hierarchical** fashion when possible - to allow for an easy navigation and discovery. The catalogue should allow data and solution providers to define the technical description of the data offerings or solutions they offer as well as information related to the offering terms and conditions such as price, SLA, license, etc.



CO-BENEFITS	Data and Solution Catalogues, such as Net Zero Cities, offer platforms for cities and stakeholders to support urban climate resilience (reducing GHG for instance), to connect local and global economy and offer education by an improved access to information. In doing so, they support public health and well-being of urban population.
EXTERNAL LINKS	Minimal Interoperability Mechanism (MIM) 3 (being developed as part of the Living-in.eu): MIM3 Plus initiative through Open 7 Agile Smart Cities or MIMs Plus 5.0 document

Data and Solution Catalogues

PRE-CONDITIONS & ENABLING CONDITIONS	***Political***: the data catalogue development must be politically independent in order not to follow interests, but to show accurate data. a solid legal base should be therefore installed, and the development process monitored, to ensure its independency. ***Economic***: same as with political interests, the impact of economic interests must be avoided at any time when developing a data catalogue for the public good and its independency ensured. ***Social***: a solid representation (data sets) of social properties within the population must be existing to provide outcome that takes social questions also into account.

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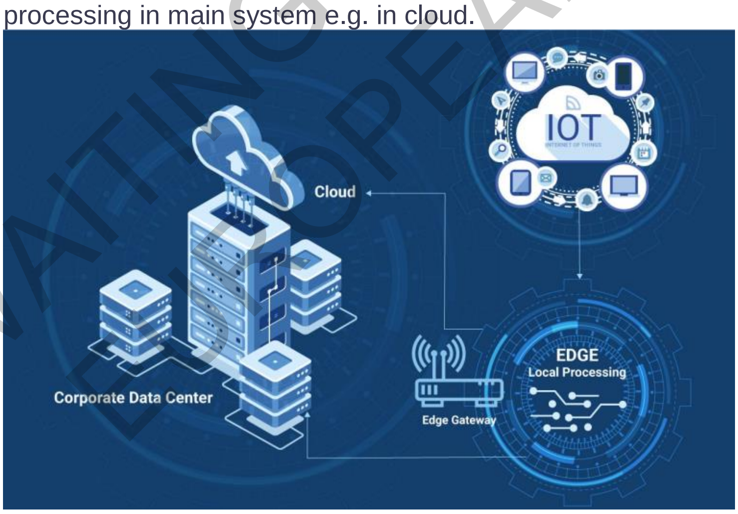
Data and Solution Catalogues	
	Technical: a digital baseline of a city, such as a 3D Model or digital twin, is a preferred way to represent collected data.
CONSTRAINTS/ BARRIERS for implementation	***Political***: political influences guided by interests. ***Economic***: economic influences guided by interests. ***Social***: involvement of existing social structures within the urban fabric can have an impact on data catalogue design principles. ***Technical***: existence and level of accuracy of existing data.
INSTRUMENTS/ Processes for implementation	Training, Awareness Campaigns
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	Greater awareness of social / economical / environmental circumstances due to availability of data that can be visualized and opened up to a broad public. Risk of misinterpreting results and visualizations can lead to faulty decisions.
IMPACTS (Indicators & DNSH)	**Reduction of CO2 emissions**, [g/tonne km], **(Change in noise level [dB]), Energy generation (UV potential MWh, Cooling of urban places (Shading) (degree Celsius)**

3.7.14 IoT Sensor & Edge Computing for Environmental Monitoring

- Authors: **OASC, VTT**
- Knowledge Repository link: **https://netzerocities.app/resource-2105**

IoT Sensor & Edge Computing for Environmental Monitoring

IoT sensors are connected devices collecting and transmitting **data over the internet**. They can be **monitoring environmental parameters** such as temperature, humidity, air quality. **Edge computing** is technology doing **data processing near the data source**, so called at the **edge network** sometimes also called also fog. Together these solutions can **improve performance and efficiency** of environmental monitoring system because less data is transferred, and local processing reduces processing in main system e.g. in cloud.



Connection of IoT and Edge computing (Source: Cuelogic)

IoT and Edge computing help cities in environmental monitoring. Cities can gather **real-time data** for different parameters in various locations and if necessary, **make informed decisions** for their resources. For instance, if an air quality sensor detects high levels of pollution, the city officials can take immediate action before it affects public health.

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IoT Sensor & Edge Computing for Environmental Monitoring	
These technologies have many benefits. They can **improve performance** of main system because **data transfer latency decreases** with **less operational costs**, and system is **less vulnerable for threats in data security**. Through gathering the environmental data, cities can **develop policies and programs** to promote sustainability and protect public health. Moreover, these technologies can support other industries like agriculture and transportation, leading to economic benefits.	
CO-BENEFITS	IoT and Edge computing provide means to **monitor environment** to **improve air quality** and **enhance wellbeing** through attractiveness. Moreover, solutions also help in **climate mitigation** through **reduced energy needs and GHG emissions**.
KEYWORDS	Technology, Monitoring, Sensing, IoT, Network, Governance and Policy
EXTERNAL LINKS	Wikipedia, web site for IoT Wikipedia, web site for Edge computing
EXAMPLES	Many cities have already launched development aiming towards being a smart city. Some practical examples for these are given in a blog post, on applying IoT in lighting and transportation (RIDGE, 2022

IoT Sensor & Edge Computing for Environmental Monitoring	
PRE-CONDITIONS & ENABLING CONDITIONS	***Political:*** Political interest on being a smart city. ***Economic:*** Funding for environmental monitoring. ***Social:*** Citizens with interest to use services. ***Technical:*** Mature companies with suitable IoT and Edge computing technologies. ***Legal:*** Regulations and policies allowing environmental monitoring.
CONSTRAINTS/ BARRIERS for implementation	***Political:*** Policymakers do not have consensus on supporting technical development towards smart city. ***Economic:*** No investments decided. ***Social:*** Citizens not supporting monitoring. ***Technical:*** Maturity of technological development varies. ***Legal:*** Regulatory and policy changes are slow and take time.
INSTRUMENTS/ Processes for implementation	• Capacity building training https://netzerocities.app/resource-1578 • Educational/ Capacity building barriers identification • https://netzerocities.app/resource-1588 • City Dashboards https://netzerocities.app/resource-2065 • Digital Twin (Built environment) https://netzerocities.app/resource-1965 • Local Digital Twin (Planning / Decision Making, cross-cutting) • https://netzerocities.app/resource-1975
DRAWBACKS/ ADVERSE	IoT and Edge computing technologies may be considered as a threat to privacy of citizens.

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IoT Sensor & Edge Computing for Environmental Monitoring	
IMPACTS of the solutions after implementation	
IMPACTS (Indicators & DNSH)	Environmental monitoring parameters available online (Estimation e.g. as percentage from all monitored items)
	No risks.

3.7.15 Vulnerability and risk information systems

- Authors: **AIT**
- Knowledge Repository link: **https://netzerocities.app/resource-2115**

Vulnerability and risk information systems	
Urban development projects are usually complex tasks where failures based on environmental circumstances, such as flooding or strong winds, can cause disastrous outcomes. With the introduction of **digital technologies** and the availability of large amounts of **data**, various data-driven methods have been developed to inform leaders of such projects upfront on future situations and any possible effects of planned developments. This allows stakeholders to **assess risks, evaluate designs and identify possible mitigations** of, for instance, flood-related causes within the planning. The integration of such analyses within computational urban modelling increases the level of information and therefore leads to more sustainable decisions for future urban developments. 	
CO-BENEFITS	Vulnerability and Risk Information Systems have the potential to **reduce risk to natural and climate hazards**, especially in cities due to early stage modelling and detection of possible future situations.
EXTERNAL LINKS	• Flooding rain drop simulation (AIT)

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Vulnerability and risk information systems	
PRE-CONDITIONS & ENABLING CONDITIONS	***Political:*** The model development must be politically independent in order not to follow individual interests, but to show an accurate outcome. A solid legal base should be therefore installed, and the development process monitored, to ensure its independency. ***Economic:*** Similar to political interests, the impact of economic interests must be avoided at any time when developing a data driven model for the public good and its independency ensured. ***Technical:*** Accurate data that can be analysed in a scientifically sound manner ***Not isolated, but integrated:*** Buildings, infrastructure, people, economy, biodiversity …. Data and model capturing the interrelations in the city
CONSTRAINTS/ BARRIERS for implementation	***Political:*** Political influences guided by individual interests ***Economic:*** Economic influences guided by individual interests ***Social:*** Involvement of existing social structures within the urban fabric can have an impact on data driven methods due to challenges of their incorporation ***Technical:*** Existence and level of accuracy of existing data
INSTRUMENTS/ Processes for implementation	Training, Awareness Campaigns
IMPACTS (Indicators & DNSH)	• Risk indicator • Early warning information • Insights for resiliency in urban planning and design, and potentially also public service design and delivery
Additional information from CASE STUDIES	• Flooding risk model • Urban Flooding and subsidence risk assessment

3.7.16 Satellite and Geospatial Data

- Authors: AIT
- Knowledge Repository link: **https://netzerocities.app/resource-2125**

Satellite and Geospatial Data
With the introduction of satellite images and geolocated data to a broad public, new opportunities are offered to city planners and governments to take informed decisions by quantitative analyses and even predictions based on these technologies. In doing so, urban phenomena, such as the relation of population demographics to current challenges of cities (as for instance, climate change in cities, crime or deprivation) can be discussed or future predictions of urban development modelled to analyse their infrastructure costs to assist cities in climate-friendly resource-efficient urban planning.

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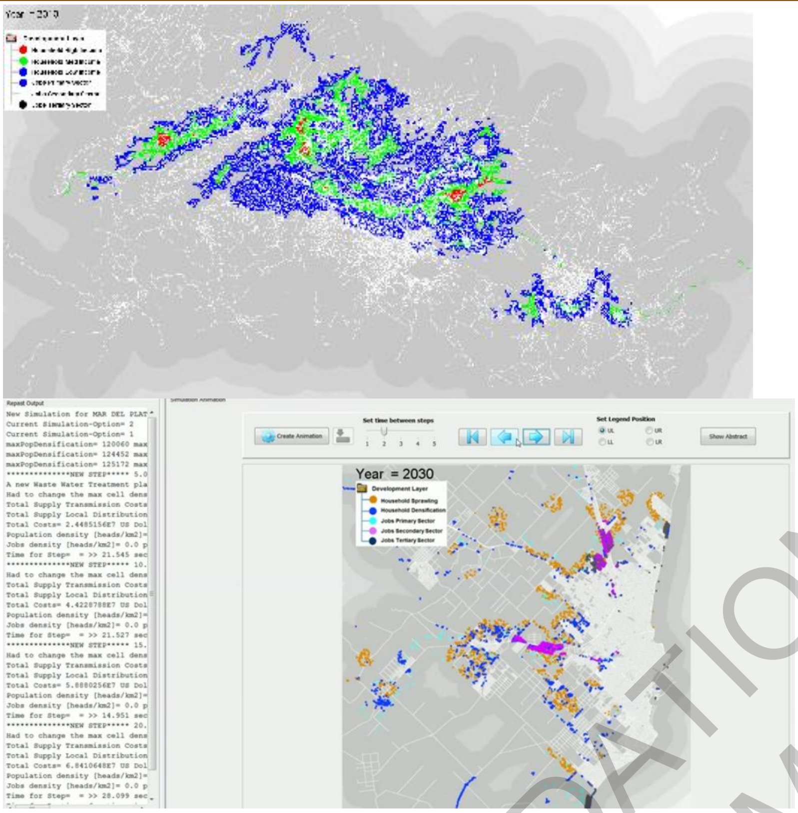
Satellite and Geospatial Data	
 *Screenshots of the tool Urban Growth Simulation Calculator*	
CO-BENEFITS	Enhance attractiveness of the cities, Healthier and more attractive lifestyles, Better access to living areas for all
EXTERNAL LINKS	• Urban Growth Simulation Calculator, City Intelligence Lab

Satellite and Geospatial Data	
PRE-CONDITIONS & ENABLING CONDITIONS	***Political:*** The model development must be politically independent in order not to follow individual interests, but to show an accurate outcome. a solid legal base should be therefore installed, and the development process monitored, to ensure its independency. ***Economic:*** Same as with political interests, the impact of economic interests must be avoided at any time when developing a satellite image-based and data driven model for the public good and its independency ensured. ***Social:*** A solid representation (data sets of satellite images, geospatial data) showing also visually social issues ***Technical:*** Accurate satellite images that can be analysed accurately and if needed joined with other data sets for a holistic view on the topic of interest.
CONSTRAINTS/ BARRIERS for implementation	***Political:*** Political influences guided by interests ***Economic:***

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Satellite and Geospatial Data	
	Economic influences guided by interests ***Social:*** Involvement of existing social structures within the urban fabric can have an impact on data driven methods due to challenges of their incorporation ***Technical:*** Existence and level of accuracy of existing satellite and geospatial data
INSTRUMENTS/ Processes for implementation	Training, Awareness Campaigns
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	Especially marginalized populations are at risk when using automated interpretation of satellite images to establish urban settlement patterns [1]. [1] Acolin, Arthur and Kim, Annette M., Seeing Informal Settlements: the Policy Implications of Different Techniques to Identify Urban Growth Patterns From Satellite Imagery Using the Case of Informal Construction in Ho Chi Minh City (2017). SLAB Working Paper Series 2017:1, Available at SSRN: https://ssrn.com/abstract=3184364 or http://dx.doi.org/10.2139/ssrn.3184364
IMPACTS (Indicators & DNSH)	Energy generation (UV potential MWh), Cooling of urban places (Shading) (degree Celsius)
Additional information from CASE STUDIES	• Attractiveness calculator • Photovoltaic potential calculator

3.7.17 Citizen Participation Platforms

- Authors: **AIT**
- Knowledge Repository link: **https://netzerocities.app/resource-2139**

As part of the collaboration with JRC in the development of the catalogue of solutions to feed the Knowledge Repository, the WP10 partner developed the "orange" fields of this solution, and then it has been afterwards reviewed by JRC and completed the "pink" fields, and the Knowledge Repository content has been updated with JRC's input. So, here only the "orange" fields developed by WP10 partners is included, and complete solution factsheet can be checked in the link to the Knowledge Repository.

Citizen Participation Platforms
Citizen Participation Platforms allow **citizens** to **take on an active part** in city governmental decisions. Such platforms allow citizens to access data about their city in an easy to understand way, enabling them to better support the decision-making process. **Local governments** are then able to tap into the ingenuity of their **residents**, gaining valuable **ideas**. This two-way feedback makes cities more **democratic and dynamic**. Residents can also play an active role in verifying and contributing to data.

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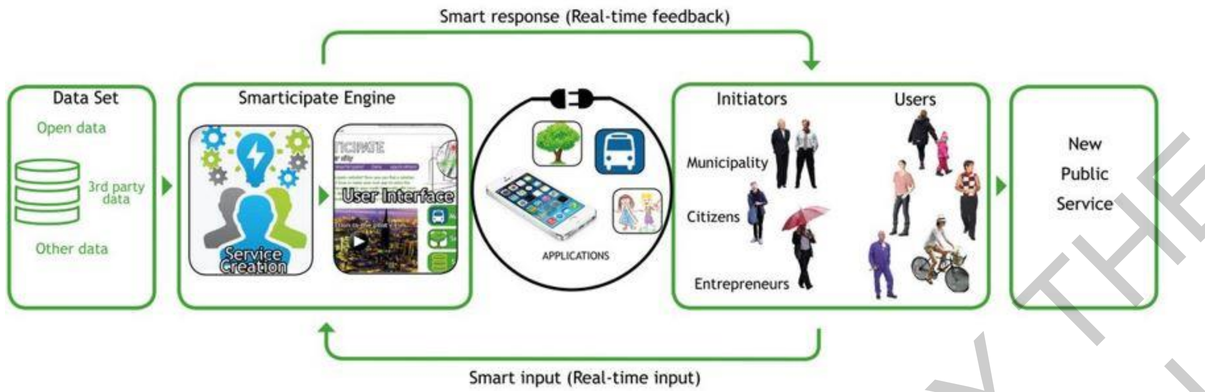
Citizen Participation Platforms



Information available to urban planners – such as applicable legal frameworks and relevant policies – can be presented to citizens, providing them with a better insight into the **planning process** and **local government decision making**.

CO-BENEFITS	Citizen participation platforms allow **enhancing citizen participation**, connectivity, and community and furthermore offer **improved access to information**, hence enhance attractiveness of the cities.
EXTERNAL LINKS	• https://www.smarticipate.eu/: Opening up the smart city

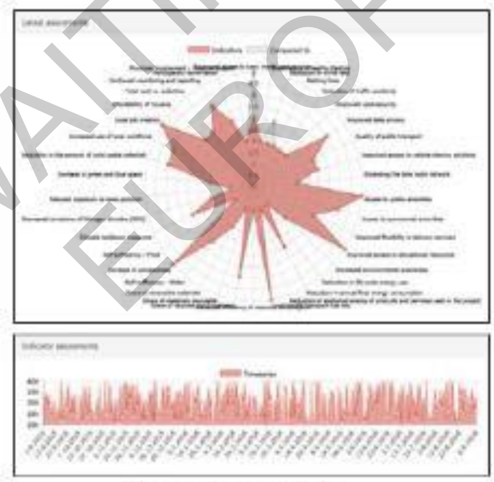
3.7.18 Measuring & Monitoring (green & digital transition)

- Authors: **VTT**
- Knowledge Repository link: **https://netzerocities.app/resource-2159**

Measuring & Monitoring (green & digital transition)

The **Measuring and Monitoring services** and tools may include the following parts:

- **learning info kit** - why measuring & monitoring is important to enable good city governance, KPIs, impact and monitoring methods,
- **data collection sources** & respective ICT technology,
- **tools and services to support measuring & monitoring** of **green and digital transitions**.



Visualized KPIs

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Measuring & Monitoring (green & digital transition)	
There are many EU research project currently running in Europe to support cities in measuring and monitoring tasks. The example of such e.g. Scalable Cities network; EU SCIS technical monitoring guide that provides cities with methodology to support monitoring activities of cities; as well as the various measuring and monitoring tools that will support cities being developed within the NetZeroCities.	
CO-BENEFITS	Monitoring is an essential component of **efficient governance**. A data-based monitoring approach supports urban planners and city decision makers with near real time data to plan and to implement right policies, technology deployment and overall urban planning activities towards **reducing GHG emissions** and **reducing energy needs**. Numerous case studies are available from "Scalable Cities" Lighthouse projects.

Measuring & Monitoring (green & digital transition)	
PRE-CONDITIONS & ENABLING CONDITIONS	***Political:*** City has plans and decisions for green & digital transition ***Technical:*** IoT, CIP, availability of data from various domains such as Energy, Building, Transport, etc.
CONSTRAINTS/ BARRIERS for implementation	Lack of availability of data from various domains such as Energy, Building, Transport, etc.
INSTRUMENTS/ Processes for implementation	• Capacity building training; https://netzerocities.app/resource-1578 • Educational/ Capacity building barriers identification https://netzerocities.app/resource-1588 • Demand management https://netzerocities.app/resource-91 • Energy management techniques https://netzerocities.app/resource-898
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	The actions made for green and digital transition needs to have follow-up counterparts to verified impacts. Otherwise, there is a possibility of incorrectly explained impacts.
IMPACTS (Indicators & DNSH)	Improved decision-making quality No risks

3.7.19 Public Code Management

- Authors: **VTT**
- Knowledge Repository link: **https://netzerocities.app/resource-2183**

Public Code Management
Public Code Management is a practice of developing and managing **publicly funded software** development openly. An ideal situation is to offer free **software for everyone**. In contrast to proprietary software development, the innovative solution is developed by public organisation with everyone able to **share, explore, utilise, and improve** the work. The core principle is responding to fundamental rights of individuals.

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Public Code Management	
*Public code movement encourages towards openness (Source: [Publiccode])* For construction industry and smart cities, there is plenty of benefits from public code that may when wisely adopted lead to **better living environments**. It can help to **create safer, more energy-efficient**, and **sustainable buildings** that contribute to **wellbeing** and **healthier buildings, structures, and infrastructures** through an enhanced collaboration and participation. For architects, engineers, or other professionals the added value is the opportunity to **reach masses of people**, who can be assigned to dedicated tasks that are communicated transparently. It ensures **transparency, accessibility**, and having **materials up-to-date**. And since the work is open source, professionals can build upon and share each other's work. The approach may also encourage social equity through creating better living environments for everyone. However, there are also challenges in openness, there should be responsible party and policy for e.g., installation, version control, distribution, and reuse.	
CO-BENEFITS	Public Code Management increases **wellbeing** by enhancing **attractiveness of the cities**. Through **sharing economy**, **local ang global innovation** helps to decrease future maintenance costs. **Social inclusion** is supported with enhancing **citizen participation and connectivity**.
KEYWORDS	Technology, Public Code, Citizen engagement, Open Source
EXTERNAL LINKS	• Publiccode.eu, web site https://publiccode.eu/en/ • Foundation for Public Code, web site https://github.com/publiccodenet
EXAMPLES	In UK "fix my street" provides an opportunity for citizens to report, view or discuss on local problems across the country, and since platform is free it has expanded to other countries.

Public Code Management	
PRE-CONDITIONS & ENABLING CONDITIONS	***Political:*** More political interest and administrative support needed. ***Economic:*** Public funding shared to many partners easily. ***Social:*** When citizen is interested to participate, they can easily see e.g. ongoing efforts. ***Technical:*** Support of industry professionals and active citizens. ***Legal:*** Responsible parties found easily, and regulations and policies support public code development.

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This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

Public Code Management	
CONSTRAINTS/ BARRIERS for implementation	***Political:*** Policymakers are not ready to order open-source solutions. ***Economic:*** Since software is free, maintenance always needs investments. ***Social:*** Not enough interaction from potential users. Openness might be sometimes considered conflicting with privacy. ***Technical:*** When large technical update is needed, it may be challenging with public code. ***Legal:*** Regulatory and policy changes are slow and take time.
INSTRUMENTS/ Processes for implementation	• Capacity building training https://netzerocities.app/resource-1578 • Educational/ Capacity building barriers identification https://netzerocities.app/resource-1588 • City Dashboards https://netzerocities.app/resource-2065 • Digital Twin (Built environment) https://netzerocities.app/resource-1965
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	Public Code Management always needs financial support for keeping it up-to-date. In built environment openness might be seen as a thread to privacy and responsible party needed.
IMPACTS (Indicators & DNSH)	Citizen engagement and public development (Estimation e.g. as percentage from all monitored items)
	No risks.

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3.7.20 Documentation of ownership data

- Authors: **AIT**
- Knowledge Repository link: **https://netzerocities.app/resource-2193**

Documentation of ownership data	
Data ownership refers to both the possession of and responsibility for information. Ownership implies power as well as control. The control of information includes not just the ability to access, create, modify, package, derive benefit from, sell or remove data, but also the right to assign these access privileges to others (Loshin, 2002). Data ownership is the right to control the use of data. It is the responsibility of the data owner to ensure that the data is used in a responsible manner and that it is kept secure. Data ownership is important because it helps to ensure that the data is used in a way that is beneficial to the data owner. It also helps to ensure that the data is not misused or abused. Data ownership is also important because it helps to ensure that the data is kept secure. Data owners have the right to control who has access to the data and how it is used. This helps to ensure that the data is not misused or abused, and that it is kept secure. Data owners also have the right to control who can access the data and how it is used.	
CO-BENEFITS	Data sets with a clear documentation of data ownership can be clearly traced back and linked to their origin source, hence can be considered reliable. Therefore, they have the potential to reduce risk to natural and climate hazards, especially in cities due to early stage modelling and detection of possible future situations.
EXTERNAL LINKS	• https://www.cambridge.org/core/books/big-data-and-global-trade-law/data-ownership-and-data-access-rights/BC314C63C58A09C4B9C5D55894FE68C6

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Documentation of ownership data	
EXAMPLES	• https://labs.centerforgov.org/data-governance/data-ownership/

Documentation of ownership data	
PRE-CONDITIONS & ENABLING CONDITIONS	***Political***: the data base development, including the documentation of ownership, must be politically independent in order not to follow interests, but to show an accurate outcome. a solid legal base should be therefore installed and the development process monitored, to ensure its independency. ***Economic***: same as with political interests, the impact of economic interests must be avoided. ***Social***: a solid representation (data sets) of social properties within the population must be existing to provide outcome that takes social questions also into account. ***Technical*** : decentralized methods (such as the blockchain) could be beneficial to document the ownership of data.
CONSTRAINTS/ BARRIERS for implementation	***Political***: political influences guided by interests ***Economic***: economic influences guided by interests ***Social***: anonymity in online platforms. ***Technical***: slow adoption of decentralized methods, such as blockchain.
INSTRUMENTS/ Processes for implementation	Training, Awareness Campaigns.
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	Might lead to less active online discussions and interactions by loss of privacy.
IMPACTS (Indicators & DNSH)	Online activities less prone to spreading false information.

3.7.21 Applying Open Standards

- Authors: **VTT**
- Knowledge Repository link: **https://netzerocities.app/resource-2203**

Applying Open Standards
Building, structure and infrastructure content in cities is exchanged many ways. When software dominates in market it may be referred as 'de facto' standard, but technical guidelines and specifications are decided by its developers. **Open standards,** on the other hand, are freely available for anyone to use without any legal, technical, or financial restrictions. Those are a set of technical guidelines that ensure **consistency and interoperability across different systems** used in different domains and disciplines. Through applying open standards in the construction industry different systems and applications can work together, regardless of the manufacturer or supplier, that leads to sustainable and comfortable living environments. There are benefits recognised that open standards usually promote innovation and competition, leading to new and improved products and services. They also lead to **increased and collaboration between industry stakeholders, resulting in cost savings, improved quality, and effective communication and decision-making**. To summarise, applying open standards in the construction industry is a positive step for companies to save time and money by reducing the need for custom solutions. There is many widely used open standards, for example Industry Foundation Classes (IFC)

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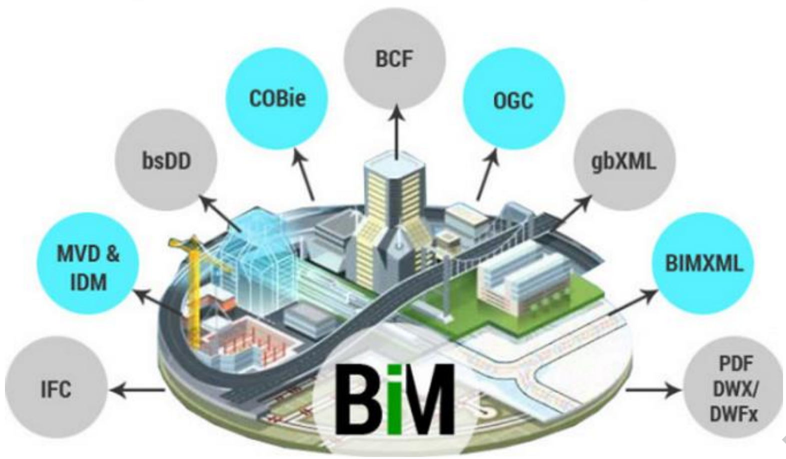
Applying Open Standards	
for buildings and bridges, LandXML and LandInfra for networks and infrastructures, and CityGML for data in cities.  *Open Standards for BIM (Source: Bimmodel)*	
CO-BENEFITS	Open Standards enable business opportunities for **easier data exchange** through enabling **interoperability** of various software. Companies may develop **innovative solutions** with higher **technological readiness**. Through model-based practices there is also **improved access to information**.
KEYWORDS	Modelling, Built Environment, Data Exchange, Open Standards
EXTERNAL LINKS	• BuildingSMART (IFC) • Open Geospatial Consortium (InfraGML, CityGML) • BuildingSMART Finland (Local LandXML 'Inframodel')
EXAMPLES	For buildings IFC (Industry Foundation Classes) data exchange format can be used by many disciplines. Architect, electrical designer, and HVAC designer can exchange data with it. There is also automated checkers that can evaluate is the compliance of the model across regulations and regional guidelines. When IFC model is communicated to different stakeholders in project, they can comment IFC models with open standard called BCF (BIM Collaboration Format).

Applying Open Standards	
PRE-CONDITIONS & ENABLING CONDITIONS	***Political:*** Decision to demand data exchange in open standard together with native formats. ***Economic:*** Investments in providing guidelines and documentation for open formats. ***Technical:*** Internal data structure in software enabling open format. ***Legal:*** Contracts including open formats in data exchange.
CONSTRAINTS/ BARRIERS for implementation	***Political:*** Large owners and clients not able to demand open formats together. ***Economic:*** No investments for guidelines and documentation. ***Technical:*** If internal data structure in software is incompatible to open standard, then it's use may demand resources.

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Applying Open Standards	
	Legal: Transparency and interoperability not requested in contracts.
INSTRUMENTS/ Processes for implementation	• Capacity building training https://netzerocities.app/resource-1578 • Educational/ Capacity building barriers identification https://netzerocities.app/resource-1588 • BIM/ CIM https://netzerocities.app/resource-2023 • Digital Twin (Built environment) https://netzerocities.app/resource-1965 • Data and Solution Catalogues https://netzerocities.app/resource-2095
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	Many open standards can describe less than half of the data included in proprietary or 'de facto' standards from suppliers. This causes the situation that projects utilizing open standards also demand data in native format (for example Archicad or Revit files from architects).
IMPACTS (Indicators & DNSH)	Number of projects demanding open standards in data exchange (Estimation e.g. as percentage from all projects)
	No risks.

3.7.22 Open Data Models & Ontologies

- Authors: **VTT**
- Knowledge Repository link: **https://netzerocities.app/resource-2213**

Open Data Models & Ontologies
Open data models refer to the sharing of data in a freely accessible format, allowing for greater transparency, collaboration, and reuse of information. In the construction industry, open data models can be applied to building information modelling (BIM), which is a digital representation a building or infrastructure. By using open data models, construction professionals can access and use building data more easily, leading to improved decision-making and increased efficiency in the design, construction, and maintenance of buildings and infrastructure. Ontologies in construction refer to a shared understanding of the meaning and relationships between concepts within a particular domain. Those are used to standardize and classify data, enabling data to be more easily shared and integrated across different systems and processes. This can improve the accuracy, consistency, and interoperability of building information, leading to increased efficiency and reduced errors. By using ontologies, construction professionals can better understand and manage the complexities of building information, supporting the development of more effective and efficient construction processes. The solution to these challenges is to adopt open data models and ontologies in the construction industry. This approach can be applied to both new building projects and existing buildings undergoing renovation or retrofitting. By using open data models and ontologies, construction professionals can access and use building information more easily and efficiently, leading to improved decision-making, reduced errors, and increased overall project efficiency. The benefits of this approach include reduced construction costs, improved project outcomes, and increased sustainability and energy efficiency. These co-benefits can lead to greater competitiveness, innovation, and resilience in the construction industry.

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Open Data Models & Ontologies

Five star open data (Source: 5stardata)

CO-BENEFITS	• Improved access to information • Efficiency in the design, construction, and maintenance of buildings and infrastructure. • Interoperability of building information
KEYWORDS	Ontology, building information, interoperability
EXTERNAL LINKS	• Linked data from Wikipedia • 5stardata • SPHERE EU project
EXAMPLES	In SPHERE EU project the open data models and ontologies were used as starting point in integration of the platforms, tools and services

Open Data Models & Ontologies	
PRE-CONDITIONS & ENABLING CONDITIONS	***Technical:*** Existing readiness to include standard approach e.g. use linked data format and skilled people to support data processes and data update
CONSTRAINTS/ BARRIERS for implementation	***Technical:*** Missing skills or/and technical readiness to adopt open data models
INSTRUMENTS/ Processes for implementation	Capacity building training https://netzerocities.app/resource-1578 Educational/ Capacity building barriers identification https://netzerocities.app/resource-1588 BIM/ CIM https://netzerocities.app/resource-2023
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	The readiness of stakeholders to produce, share and use open data models and ontologies varies a lot. The incorrect use of ontology or open data can lead to errors.
IMPACTS (Indicators & DNSH)	The use of open data models can increase interoperability and lead to time and cost savings both in the constructions phase and in use and renovations because of models.
	No risks
Additional information from CASE STUDIES	Case study examples in SPHERE project

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3.7.23 Local Data Spaces Policy

- Authors: **VTT**
- Knowledge Repository link: **https://netzerocities.app/resource-2223**

Local Data Spaces Policy	
The local data spaces policy in the construction industry refers to the creation of digital representations of a building's data in a **secure and controlled environment**. This includes information about the design, construction, and operation of the building, such as building plans, specifications, schedules, and energy consumption data. The purpose of this policy is to provide a centralized repository of building data that can be easily accessed and shared by all stakeholders, including designers, contractors, owners, and building occupants. By having all relevant information in one place, the **local data spaces policy aims to improve collaboration, increase transparency, and reduce errors in the building process**. Additionally, it provides a valuable source of information for ongoing building operations and maintenance, allowing building managers to make informed decisions about energy use, maintenance schedules, and upgrades. The policy can be applied to both new buildings and existing buildings, and the benefits **include improved project delivery, reduced waste, increased efficiency, and enhanced building performance**. In terms of implementation, the local data spaces policy is typically established through a combination of technological solutions, such as building information modelling (BIM) software, and best practices for data management. This can involve creating a digital twin of the building, which provides a virtual representation of the physical building and its systems. By using BIM software and other tools, stakeholders can access, share, and **collaborate on building data in real-time, reducing the risk of errors and improving project delivery.**	
CO-BENEFITS	Improved project delivery, Reduced waste, Increased efficiency, Enhanced building performance.
KEYWORDS	Data spaces, collaboration, building process
EXTERNAL LINKS	EU initiative for dataspaces
EXAMPLES	EU has launched an initiative to provide dataspaces for cities in 2022. The goal is Develop a multi-stakeholder data governance scheme by bringing together European cities and their local stakeholders.

Local Data Spaces Policy	
PRE-CONDITIONS & ENABLING CONDITIONS	***Technical:*** The use of dataspaces needs specifications of valid open source and commercially available implementations of specifications
CONSTRAINTS/ BARRIERS for implementation	***Technical:*** If there is lack of stable specifications together with valid open source and commercially available implementations, then errors will occur.
INSTRUMENTS/ Processes for implementation	• Capacity building training https://netzerocities.app/resource-1578 • Educational/ Capacity building barriers identification https://netzerocities.app/resource-1588 • Open data models: https://netzerocities.app/resource-2213 • BIM/CIM https://netzerocities.app/resource-2023
DRAWBACKS/ ADVERSE IMPACTS of the	Depending on the stability of specifications and implementations, local data spaces might mean great changes and their uptake through the industry and its stakeholders take effort and time.

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Local Data Spaces Policy	
solutions after implementation	
IMPACTS (Indicators & DNSH)	Improved project delivery, reduced waste, increased efficiency, and enhanced building performance.
	No risks

3.7.24 Living.in-EU / MIM Plus

- Authors: **OASC, VTT**
- Knowledge Repository link: **https://netzerocities.app/resource-2237**

Living.in-EU / MIM Plus
Minimal Interoperability Mechanisms (MIMs) are the minimal but sufficient capabilities needed to achieve interoperability of data, systems, and services between buyers, suppliers and regulators across governance levels around the world. Because the mechanisms are based on an inclusive list of baselines and references, they take into account the different backgrounds of cities and communities and allow cities to achieve interoperability based on a minimal common ground. The MIMs are aimed to provide solutions that will work internationally. **MIMs plus** is a version of the MIMs where each MIM is linked to the EU policy context and are managed through **Living-in.eu** Implementation can be different, as long as crucial interoperability points in any given technical architecture use the same interoperability mechanisms. The MIMs are vendor neutral and technology agnostic, meaning that anybody can use them and integrate them in existing systems and offerings, complementing existing standards and technologies. The Minimal Interoperability Mechanisms (MIMs) start from identifying what cities need to develop a local data ecosystem and then to provide a complete set of building blocks that will enable a city to put it in place. The aim for each MIM is to provide sufficient interoperability to allow "good enough" integration of systems and the development of a viable market – cutting costs, minimising risk and preventing vendor lock-in. They will be "Minimal" to ensure there is no unnecessary complexity or time-to-implement, with the aim that the cost for cities to implement (staff time, software, hardware) will be less than, say, €50,000. They will provide a clearly defined mechanism so that It is easy to determine if a product or service is compliant and to identify what steps are needed to implement them. These are not completely new pieces of work. Where there are existing authoritative standards, the MIM will point to the most important standards and the core requirements of those standards that a city could put in place as a first step to start to see immediate benefit in developing the local data ecosystem. Where there are several standards initiatives that cover the same ground, the aim will be to identify the lowest common denominator (or the NIST Pivotal Points of Interoperability) that will make it easy to link products and services that comply with those different sets of standards. Where policy or procurement requirements have been agreed, but there are no technical specifications to support these, then, and only then, the MIMs will aim to fill this gap. By promoting the construction of energy-efficient and environmentally friendly buildings, "Living.in-EU" and "MIM Plus" aim to contribute to a more sustainable built environment in the European Union.

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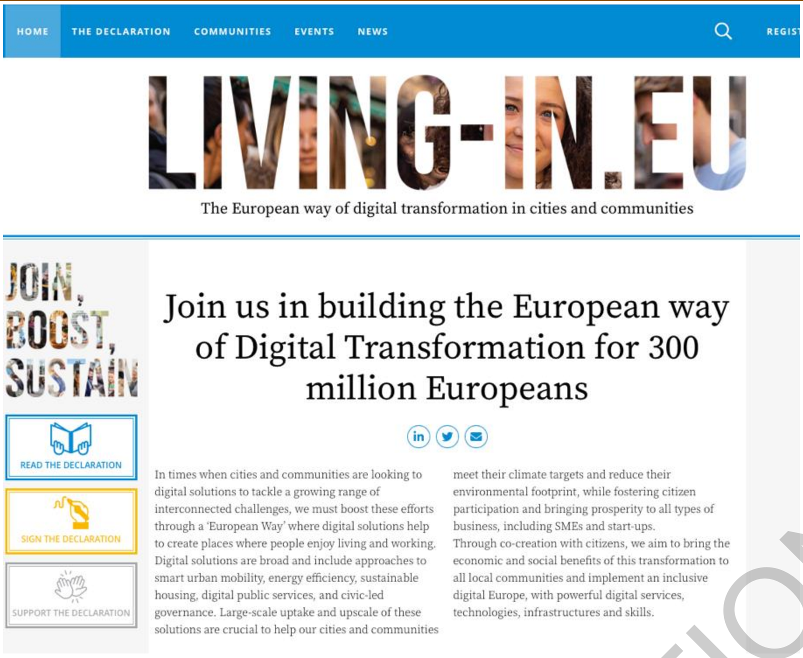
Living.in-EU / MIM Plus



Living-In.eu site promoting digital transformation (Source: https://living-in.eu)

CO-BENEFITS	Better business via easy-to-link products and services that comply with those standards
KEYWORDS	Minimal Interoperability Mechanisms
EXTERNAL LINKS	• Living-In.eu: https://living-in.eu/ • Minimal Interoperability Mechanisms: • https://living-in.eu/group/commitments/mims-plus-version-5-final
EXAMPLES	Scaling digital solutions with Open & Agile Smart Cities (OASC).

Living.in-EU / MIM Plus	
PRE-CONDITIONS & ENABLING CONDITIONS	***Technology:*** Buildings must meet certain criteria related to energy efficiency, indoor air quality, materials, and other sustainability factors
CONSTRAINTS/ BARRIERS for implementation	***Technology:*** Lack of minimal capabilities needed to achieve interoperability of data, systems, and services
INSTRUMENTS/ Processes for implementation	• Capacity building training https://netzerocities.app/resource-1578 • Educational/ Capacity building barriers identification https://netzerocities.app/resource-1588
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	Lack of interoperability prevents gaining impacts using MIMplus principles.
IMPACTS (Indicators & DNSH)	New services arising from easy-to-link principle of MIM
	No risk

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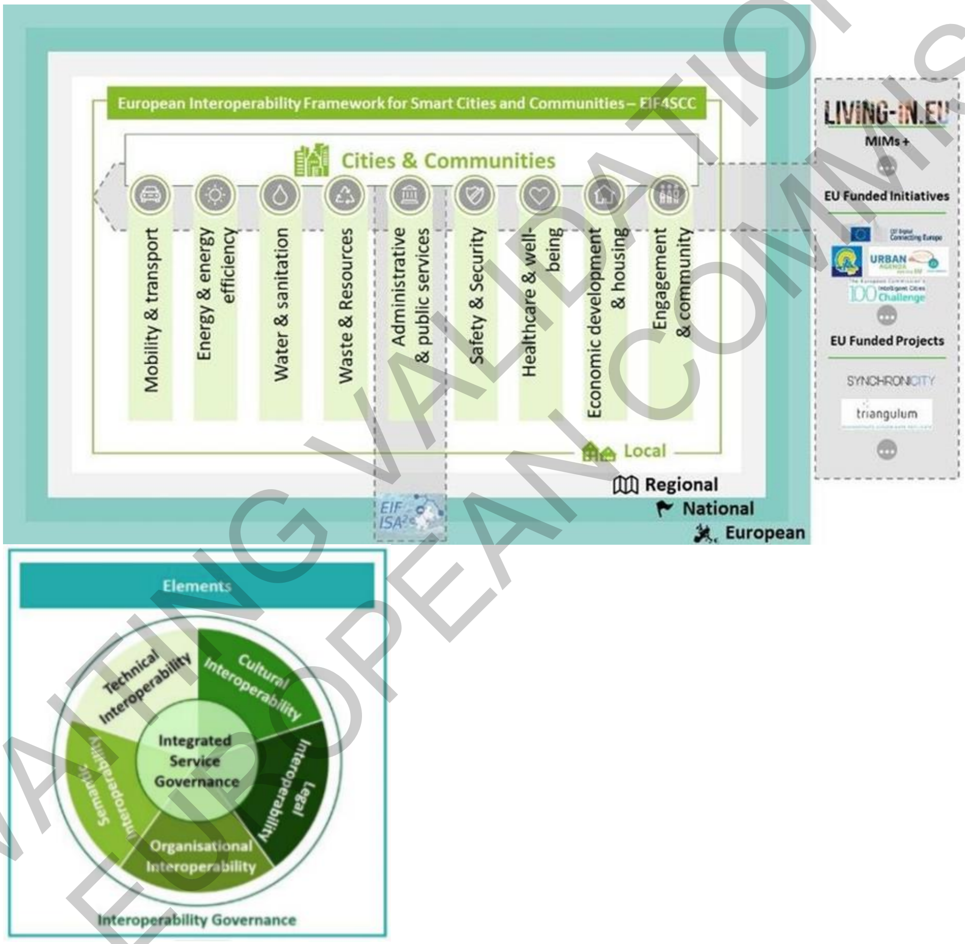
3.7.25 European Interoperability Framework for Smart Cities and Communities (EIF4SCC)

- Authors: **OASC, VTT**
- Knowledge Repository link: https://netzerocities.app/resource-2247

European Interoperability Framework for Smart Cities and Communities (EIF4SCC)
Interoperable Europe is an **initiative** of the European Commission for a **reinforced interoperability policy in the public sector**. It evolved out of the ISA² funding programme of the European Union that supported the development of digital solutions to enable public administrations, businesses, and citizens in Europe to benefit from interoperable cross-border and cross-sector public services. That programme finished at the end of December 2020. The issue, of course, is still not solved, and so the European Commission and its partners in public administrations across Europe are now working under the label of Interoperable Europe to continue to enhance interoperability to **unlock the potential of data use and reuse for improved public services**.  A **recent study** by the European Commission's Joint Research Centre (**JRC**) states that improved interoperability could lead to a **reduction in the time citizens spend every year with the administration by 25%**. This would result in time savings of 24 million hours (about 2738 years) and monetary savings in the order of EUR 543 million per year. For business, the savings could reach up to EUR 568 billion annually. Interoperable Europe will lead the process of achieving these goals and creating a reinforced interoperability policy that will work for everyone. It is committed to introducing a new cooperative

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European Interoperability Framework for Smart Cities and Communities (EIF4SCC)	
Interoperability policy Directive for Europe that will transform the public administrations and help them in their digital transformation. The initiative is supported by the Digital Europe programme. As part of this wider push for interoperability the Proposal for a European Interoperability Framework for Smart Cities and Communities (EIF4SCC) was published in May 2021. The aim is to focus on the specific needs and opportunities that interoperability provides in the local context. The Proposal is being discussed through the Living-in.EU community and other fora, with a view to its adoption as an official Commission document, based on users' and stakeholders' feedback. By complying with the EIF4SSC, cities can more easily benefit from solutions developed elsewhere and solutions providers would have access to a large potential market for their products.	
CO-BENEFITS	Interoperability is seen as an important enabler for **entrepreneurship and innovation**, facilitating **data sharing and reuse**. enhancing citizen participation when collecting the users' and stakeholders' feedback
KEYWORDS	• Governance and policy, • Climate resilience, • Analytics and modelling, • Technology • **Sustainable,** • **Secure,** • **And efficient.**
EXTERNAL LINKS	• Proposed European Interoperability Framework for Smart Cities & Communities (EIF4SCC)
EXAMPLES	• Triangulum project

European Interoperability Framework for Smart Cities and Communities (EIF4SCC)	
PRE-CONDITIONS & ENABLING CONDITIONS	***Political:*** There is a need for the cities and communities participation in some domain ***Social:*** There is an understanding in the city on the importance of interoperability at the local level.
CONSTRAINTS/ BARRIERS for implementation	***Technological:*** Level of technology below the needed for interoperability concepts
INSTRUMENTS/ Processes for implementation	• Capacity building training https://netzerocities.app/resource-1578 • Educational/ Capacity building barriers identification https://netzerocities.app/resource-1588 • Living.in-EU / MIM Plus https://netzerocities.app/resource-2237
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	The unlocked public data needs to be interoperable with intended public services.
IMPACTS (Indicators & DNSH)	Improved public services due to reuse of unlocked data
	No risks

3.7.26 United for Smart Sustainable Cities (U4SSC) Publications

- Authors: **AIT**

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- Knowledge Repository link: **https://netzerocities.app/resource-2267**

United for Smart Sustainable Cities (U4SSC) Publications	
The **United for Smart Sustainable Cities (U4SSC)** is a global initiative that provides an international platform for **information exchange and partnership** building to guide cities and communities in achieving the UN Sustainable Development Goals. The U4SSC is a UN initiative coordinated by ITU, UNECE and UN-Habitat and supported by other 16 UN bodies, that help support the development of institutional policies and strategies which encourage the use of digital technologies to facilitate digital transformation and ease the transition to smart sustainable cities. The U4SSC supports cities on their **digital transformation journey** in order to meet their goals and targets and create the cities and communities of tomorrow.	
CO-BENEFITS	U4SSC serves as the global platform to advocate for public policy and to encourage the use of ICTs to facilitate and ease the transition to smart sustainable cities. Therefore, it is seen as an important enabler for social inclusion and education by improving access to information and increase skill development.
EXTERNAL LINKS	• https://u4ssc.itu.int/publications/
EXAMPLES	• https://www.itu.int/en/publications/Documents/tsb/2023-U4SSC-Compendium-Practices-Innovative-Financing-SSC-Projects/index.html#p=1 • https://www.itu.int/en/publications/Documents/tsb/2022-U4SSC-Smart-tourism/index.html#p=1

United for Smart Sustainable Cities (U4SSC) Publications	
PRE-CONDITIONS & ENABLING CONDITIONS	***Political***: the publications must be politically independent in order not to follow interests, but to show an accurate outcome. ***Economic***: the impact of economic interests within publications must be avoided at any time. ***Social***: no one is left behind with accessing publications. ***Technical***: an independent platform, such as U4SSCC, must be installed to host independent publication.
CONSTRAINTS/ BARRIERS for implementation	***Economic***: Economic influences guided by interests. ***Social***: Online access only might lead to leaving people without access to the internet behind. ***Legal***: dependent from webpage host.
INSTRUMENTS/ Processes for implementation	Trainings, Awareness Campaigns
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	Raising awareness and education leads to increasing discussions on higher level.
IMPACTS (Indicators & DNSH)	• A rise in interest • Increasing questioning decisions • More discussions

3.7.27 Agile systems development (prototyping & sandboxes)

- Authors: **VTT**

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This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

- Knowledge Repository link: https://netzerocities.app/resource-2277

Agile systems development (prototyping & sandboxes)	
Agile systems development, including prototyping and sandboxes, is a method of software development that emphasizes collaboration, flexibility, and rapid iteration. This approach is based on the **Agile Manifesto,** which advocates for a more flexible and responsive development process that can adapt to changing requirements and customer needs. In the construction industry, Agile systems development can be used to create digital tools and solutions that **support the design, construction, and operation of buildings**. Prototyping and sandboxes are key components of Agile systems development. Prototyping involves creating a working model of a system or solution, allowing stakeholders to see how it will work in practice. This can help to identify any issues or improvements that need to be made before the final solution is developed. **Sandboxes are isolated testing environments** that can be used to experiment with new solutions or technologies. This allows developers to try out new ideas and approaches without disrupting the existing systems or workflows. The use of Agile systems development in the construction industry can help to **increase the speed and efficiency of project delivery**. By using rapid prototyping and sandboxes, stakeholders can quickly test and refine new solutions, reducing the risk of errors and delays. It also allows teams to be more flexible and responsive to changing requirements and customer needs, **improving the overall quality** of the final solution. The use of Agile systems development in construction can lead to better collaboration and communication between stakeholders, **reducing the risk of misunderstandings and improving the overall success of projects.**	
CO-BENEFITS	• Increased collaboration • Increase the speed and efficiency of project delivery • Improving the overall quality
KEYWORDS	Rapid prototyping, Sandboxes, Digital tools
EXTERNAL LINKS	Principles of Agile manifesto
EXAMPLES	Existing software example for agile construction by Trimble

Agile systems development (prototyping & sandboxes)	
PRE-CONDITIONS & ENABLING CONDITIONS	***Political:*** Empower Individuals and interactions (collaboration) over processes and tools ***Technical:*** Commit to Working software over comprehensive documentation & Responding to changeover following a plan ***Social:*** Customer collaboration in key role
CONSTRAINTS/ BARRIERS for implementation	***Technical:*** Lack of expertise in using and maintaining the software over comprehensive documentation & Responding to change over following a plan
INSTRUMENTS/ Processes for implementation	• Capacity building training https://netzerocities.app/resource-1578 • Educational/ Capacity building barriers identification https://netzerocities.app/resource-1588 • BIM/ CIM https://netzerocities.app/resource-2023
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	If There is a lack of collaboration and definitions, the result may not meet expectations.
IMPACTS (Indicators & DNSH)	Cost savings in design, construction and maintenance
	No risks

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3.8 Enabling Instruments

In this section, the Enabling Instruments reported in previous deliverable are gathered. They have been partially updated since they were delivered in the previous D10.2. They serve mainly as link to support the implementation of the other technical solutions, and, as enablers themselves, they do not have an associated "pink" fields part.

- **Knowledge Repository: Enabling Instruments: https://netzerocities.app/resource-2646**

Table 10: Enabling Instruments solutions

Enabling Instruments		Section
Educational, Capacity Building instruments	User Engagement for Energy Performance Improvement	3.8.1
	Local energy communities	3.8.2
	Cooperatives	3.8.3
	Educational activities on NBS	3.8.4
	Supporting municipalities to monitor resource flows in line with impact targets and measurement processes	3.8.5
	Capacity building and engagement with municipalities to identify and co-create circular solutions and roadmaps	3.8.6
	Capacity building for city officials to understand urban metabolisms and circular solution opportunities	3.8.7
	Capacity building and training	3.8.8
	Educational/ Capacity building barriers identification	3.8.9
Involving, Collaborating and Empowering instruments	Urban-scale environmental decision support system (DSS) based on EPC (Energy Performance Certificate) databases	3.8.10
	Engagement, co-creation and co-design of NBS and Green Infrastructure plans and interventions	3.8.11
	City coaching in NBS	3.8.12
	Platform for Enhancing Multi Stakeholder Dialogue to Implement NBS across EU	3.8.13
	Gender diversity considerations in urban mobility	3.8.14
Financial instruments	Loans for Energy Efficiency (EE)	3.8.15
	Blended finance for Energy Efficiency (EE)	3.8.16
	Road/ Congestion pricing in transport	3.8.17
Planning instruments	Integrated land use and urban planning with energy and climate	3.8.18
	Integrated land use planning and urban space management with mobility planning	3.8.19
	Integrated climate plans for cities (i.e. SECAPs)	3.8.20
	Sustainable Urban Mobility Plan (SUMP)	3.8.21
	Decarbonisation Plans for Industry	3.8.22
	City water resilience assessment	3.8.23
Policy instruments	Governance EU Climate Neutrality Framework	3.8.24
	Data strategy	3.8.25
Regulatory instruments	Public procurement for innovative NBS and Green Infrastructure interventions	3.8.26
	Building Renovation Passport (BRP)	3.8.27
	Smart Readiness Indicator (SRI)	3.8.28
	Mobility Management	3.8.29
	Urban Vehicle Access Regulations (UVAR)	3.8.30
	Low-Emission Zones	3.8.31

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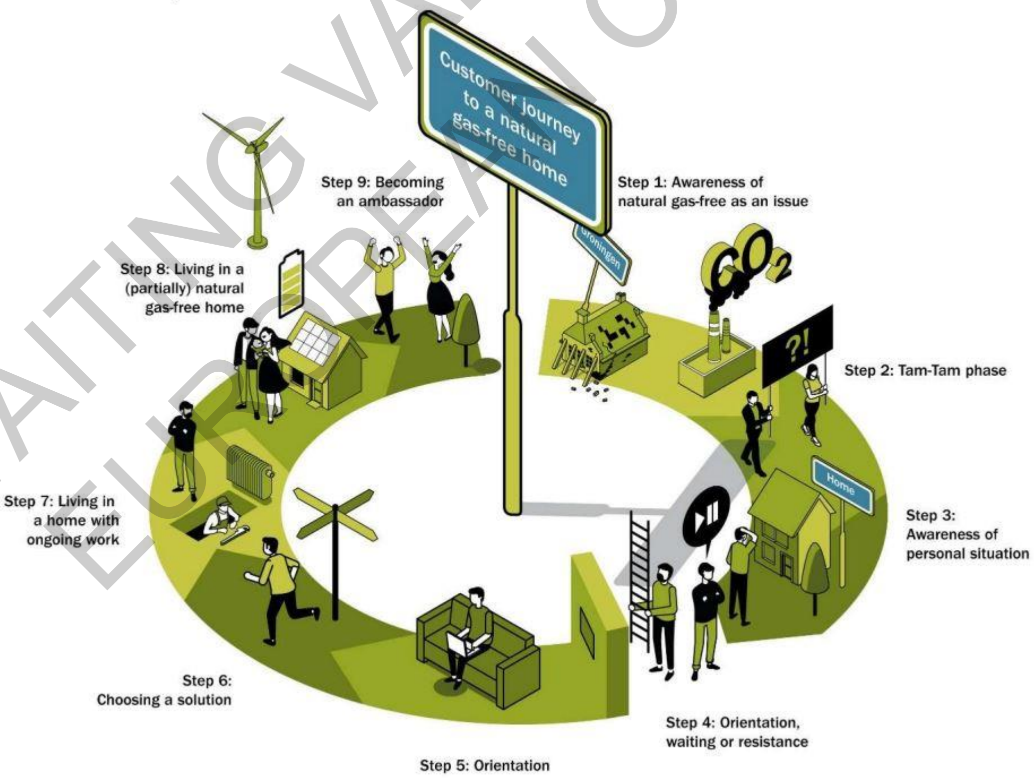
This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

Enabling Instruments		Section
	NBS and Green Infrastructure regulation and ordinances	3.8.32
	NBS and Green Infrastructure plans and strategy design and governance	3.8.33
	Building Material Passport (BIM-based)	3.8.34
Technical instruments	Turnkey Retrofit service	3.8.35
	Integrated Energy and GHGs scenario mapping tools	3.8.36
	NBS and Green Infrastructure Mapping	3.8.37
	Analysis of City/ (Building) circularity	3.8.38
	Circular economy design principles to increase the durability, reparability, upgradability or reusability of products	3.8.39
	Urban metabolism mapping	3.8.40
	Circular Life Cycle Assessment/Analysis for material and products	3.8.41
	One-stop-shop for building renovation	3.8.42

3.8.1 User Engagement for Energy Performance Improvement

- Authors: **TNO**
- Knowledge Repository link: https://netzerocities.app/resource-1498

User Engagement for Energy Performance Improvement
The energy transition has far-reaching effects on the direct living environment of citizens. **Changes at home**, neighbourhood, and environment are necessary in order to achieve goals related to energy conservation and the generation of sustainable energy. The extent to which residents are involved in the process of making sustainable decisions has an important impact on the speed and outcome of such projects.



Customer journey to a natural gas-free home. Source: TNO, Natural gas-free homes: drivers and barriers for residents

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<table>
<tr><th colspan="2">User Engagement for Energy Performance Improvement</th></tr>
<tr><td colspan="2">

Residents want to and should have influence and feel involved in the decisions over plans related to **energy transition**, as their participation is crucial to make it a success. When this happens carelessly, it can lead to concerns, discussions and a distancing of citizens from project initiators.

Multiple approaches for successful citizen and consumer **engagement** have been developed, focusing on specific **target groups**, e.g. tenants of housing corporations and home owner associations. Important elements of these approaches are getting insights into the drivers, barriers, and values of citizens and consumers. In some of these methods, an essential element is **creating social cohesion**.

The **benefits** are energy solutions that match with citizen's needs, preventing or reducing resistance. Accordingly, the outcome of this engagement reduces the use of energy as well as fosters the adoption of sustainable energy solutions by end users.
</td></tr>
<tr><td>**CO-BENEFITS**</td><td>Such a solution can bring benefits with respect to **climate resilience**, climate mitigation, climate adaptation. Further it can **support the economy**, via local and global connection, **social inclusion**, **social education and health**, in terms of environment and wellbeing.</td></tr>
<tr><td>**KEYWORDS**</td><td>It is directly linked to solutions such as integrated urban energy and climate plans; smart solutions; user engagement, energy performance improvement, and other sustainable decisions.</td></tr>
<tr><td>**EXTERNAL LINKS**</td><td>The following **citizen and consumer engagement methods/approaches** are available:

- Natural gas-free homes: drivers and barriers for residents (TNO report), it provides an overview of the drivers and barriers that residents experience at the different steps of the customer journey to a natural gas-free home.
- Becoming sustainable together with residents: participation and communication manual for housing corporations (POCITYF project). Sustainable houses have a great impact on residents but tenants often dread changes and are not willing to take part in the energy transition process when not deliberately opposing it. It is essential that house corporations involve their tenants in sustainable houses projects. However, doing so may not be easy. The manual is a step-by-step guide designed for housing corporations to engage with other stakeholders in the energy transition landscape. It is important that house corporations understand that they must go beyond energy topic if they want to connect with the house tenants.
- Overview of barriers and drivers for consumer engagement in demand response (BRIGHT project). Consumer/citizen engagement is considered as one of the effective tools to unlock demand response potential. The emergence of distributed energy resources and digitalization allows for new ways for consumer/citizen engagement through various forms of energy communities. The emergence of energy communities and their potential engagement in demand response activities bring along new interactions and dynamics in the energy system. Demand response can contribute towards fulfilling energy communities' objectives such as
</td></tr>
</table>

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User Engagement for Energy Performance Improvement	
	increased self-consumption, cost-effectiveness, sustainability as well as energy independence. The report contains a preliminary version of citizen engagement framework which will be co-created and enhanced together with active participation of BRIGHT pilots.

3.8.2 Local energy communities

- Authors: **Energy Cities**
- Knowledge Repository link: **https://netzerocities.app/resource-618**

Local energy communities	
Energy communities refer to a wide range of collective energy actions that involve citizens' participation in the energy system. They can be understood as *a way to organise collective energy actions around open, democratic participation and governance, and the provision of benefits for the members or the local community.* It is a broad concept, that c**an refer to collective switching campaigns, collective investments in solar panels, but also the ownership of an energy supply company, or even a distribution network.** Depending on their activity and on the national regulatory framework where they operate, energy communities **can take different forms and legal entities**, like cooperatives, partnerships, companies with a community interest, foundations, non-profit organisations, trusts, and associations. It makes it easier for its citizens, together with other market players, to team up and jointly invest in energy assets. Energy communities contribute to i**ncreasing public acceptance of renewable energy projects and make it easier to attract private or citizen investments in the clean energy transition.** They provide direct benefits to citizens by advancing energy efficiency and lowering their electricity bills, thus contributing to fighting energy poverty. Aligned with local policies for decarbonisation and decentralised energy production, they lead to long-term and trustful partnerships between municipalities and local or regional stakeholders. They are **recognised as a fertile ground for social innovation.** The most successful energy **community projects in Europe are those where groups collaborate with local authorities.** Local or regional governments have everything to gain from promoting the scale-up of energy communities in their area. They can initiate new projects themselves (create an example, like Ollersdorf), take part directly in one or several communities, or indirectly support them, for instance by creating a more favourable local regulatory framework, such as tax discounts or e-platforms to enrol in energy communities or register them. Through the **Clean energy for all Europeans package** adopted in 2019, the EU has introduced the concept of energy communities in its legislation, notably as c**itizen energy communities and renewable energy communities.** There are two European directives that refer to two figures of energy communities: Citizen energy communities (Article 2(11) Recast Electricity Directive) and Renewable energy communities (Article 2(16) Recast Renewable Energy Directive). The **main difference is that the former one is purely electrical, while the second one is more restrictive (in terms of who can participate in it and operate it) and involves all energy carriers (e.g. heat and power).** Check Q&A of RESCoop for more information	
CO-BENEFITS	The following co-benefits can be tackled: • Increase access to clean, affordable, and secure energy • Proximity economy • Enhancing citizen participation, connectivity, and community • Improved access to information • Raised awareness/behavioural change
EXTERNAL LINKS	• Dedicated page on the portal of the European Commission: https://energy.ec.europa.eu/topics/markets-and-consumers/energy-communities_en

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Local energy communities	
	• Caramizaru, E. and Uihlein, A., Energy communities: an overview of energy and social innovation, 2020: https://publications.jrc.ec.europa.eu/repository/handle/JRC119433 • Energy Cities, Community Energy: A practical guide to reclaiming power, 2020: https://energy-cities.eu/wp-content/uploads/2020/10/Community-Energy-Guide-web.pdf • Transposition of energy communities directives tracker: https://www.rescoop.eu/policy#transposition-tracker • Q&A of energy communities: https://www.rescoop.eu/uploads/rescoop/downloads/QA-What-are-citizens-energy-communities-renewable-energy-communities-in-the-CEP.pdf • EU projects about energy communities: https://www.localres.eu/about-the-project/related-projects-and-initiatives/

3.8.3 Cooperatives

- Authors: **Energy Cities**
- Knowledge Repository link: **https://netzerocities.app/resource-1508**

Cooperatives

The International Cooperative Alliance defines **cooperative** as "an autonomous association of persons united voluntarily to meet their common economic, social and cultural needs and aspirations through a jointly owned and democratically controlled enterprise".

Cooperatives are **people-centred enterprises owned**, controlled and run by and for their members to realise their common economic, social, and cultural needs and aspirations.

Cooperatives bring people together in a **democratic and equal way**. Whether the members are the customers, employees, users or residents, cooperatives are democratically managed by the 'one member, one vote' rule. Members share equal voting rights regardless of the amount of capital they put into the enterprise.

Edimburg Solar Cooperative launch

As businesses driven by values, not just profit, cooperatives share internationally agreed principles and act together to build a better world through cooperation. Putting **fairness, equality and social justice** at the heart of the enterprise, cooperatives around the world are allowing people to work together to create sustainable enterprises that generate long-term jobs and prosperity.

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Cooperatives	
Cooperatives **allow people to take control of their economic future** and, because they are not owned by shareholders, the economic and social benefits of their activity stay in the communities where they are established. Profits generated are either reinvested in the enterprise or returned to the members. Cooperatives are the major **business model** of **energy communities** in Europe, representing about 3500 of them.	
CO-BENEFITS	Some of the related co-benefits are: • Increase access to clean, affordable, and secure energy • Proximity economy • Enhancing citizen participation, connectivity, and community • Improved access to information • Raised awareness/behavioural change
EXTERNAL LINKS	• The International Cooperative Alliance: https://www.ica.coop/en • The European federation of citizen energy cooperatives REScoop: https://www.rescoop.eu/

3.8.4 Educational activities on NBS

- Authors: **METABOLIC**
- Knowledge Repository link: **https://netzerocities.app/resource-1518**

Educational activities on NBS

Education plays a fundamental role in fostering sustainability literacy and awareness, and Nature-based Solutions (**NBS**) are an excellent tool to address the topic. Considering the era of unprecedented global changes our societies are experiencing, among which climate change is one of the most notable examples, the urgency of **raising awareness** and sparking action is ever more prominent.

In this context, education plays a fundamental role in **fostering knowledge** about the interplay between **nature and society** and the exploration of how to **develop resilient and inclusive communities**. Among other tools, NBS have emerged as a way to address these needs.

Different educational activities can be adapted to a specific audience and time, based on the different **stakeholders involved** (including schools, adult citizens, NBS professionals, unemployed, policy makers) and logistical circumstances such as the time, budget, and capacity that are available. Different **activities** can include workshops, lectures, conferences or training courses, but can also go beyond these common activities (exhibitions, think-and-do-tanks, etc.). Since the start of the pandemic, online activities provide the opportunity to reach out to larger audiences whilst saving organisational costs. Activities such as Massive Open Online Courses (MOOCs) and webinars have been gaining increasing popularity.

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Educational activities on NBS	
CO-BENEFITS	Educational activities have a strong impact on social and economic aspects: First of all, educational activities contribute to increase **social cohesion and social capacity building** and enhance **citizen participation, connectivity and community**. At the same time, they promote improved **access to information** and can lead to **raise awareness/behavioural change**, increase skill development and improve **access to job opportunities**. With regards to economic aspects, educational activities improve **local and global connection by boosting local business (km 0)** and by fostering a **proximity economy** and sharing economy. At the same time, educational activities can help to increase employment rate and technological readiness.
EXTERNAL LINKS	• MOOC: Nature-based Metropolitan Solutions • MOOC: Nature-based solutions for Disaster and Climate Resilience (UNEP) • EcoActive: Learning Resources, outdoor learning activities (activities that give you a great excuse to get out and about in nature) • Smart City Expo World Congress
EXAMPLES	• Nabolagshager, Oslo: green and social cities • SALUSSPACE, Bologna: Sustainable Accessible Liveable Usable social space for intercultural Wellbeing, Welfare and Welcoming • De Ceuvel Aquaponics Workshops, Amsterdam

3.8.5 Supporting municipalities to monitor resource flows in line with impact targets and measurement processes

- Authors: **Tecnalia**
- Knowledge Repository link: **https://netzerocities.app/resource-1528**

Supporting municipalities to monitor resource flows in line with impact targets and measurement processes
Measuring and monitoring resource flows is key to enable an effective understanding of how cities work in terms of their fundamental stocks and flows, and consequently, to **identify circular economy opportunities**. Ideally, any circular solution should be based on a comprehensive analysis of the urban metabolism and a monitoring scheme should be settled since the early stages to evaluate the progresses towards circular loops on the one hand, and to overarching sustainable goals on the other.

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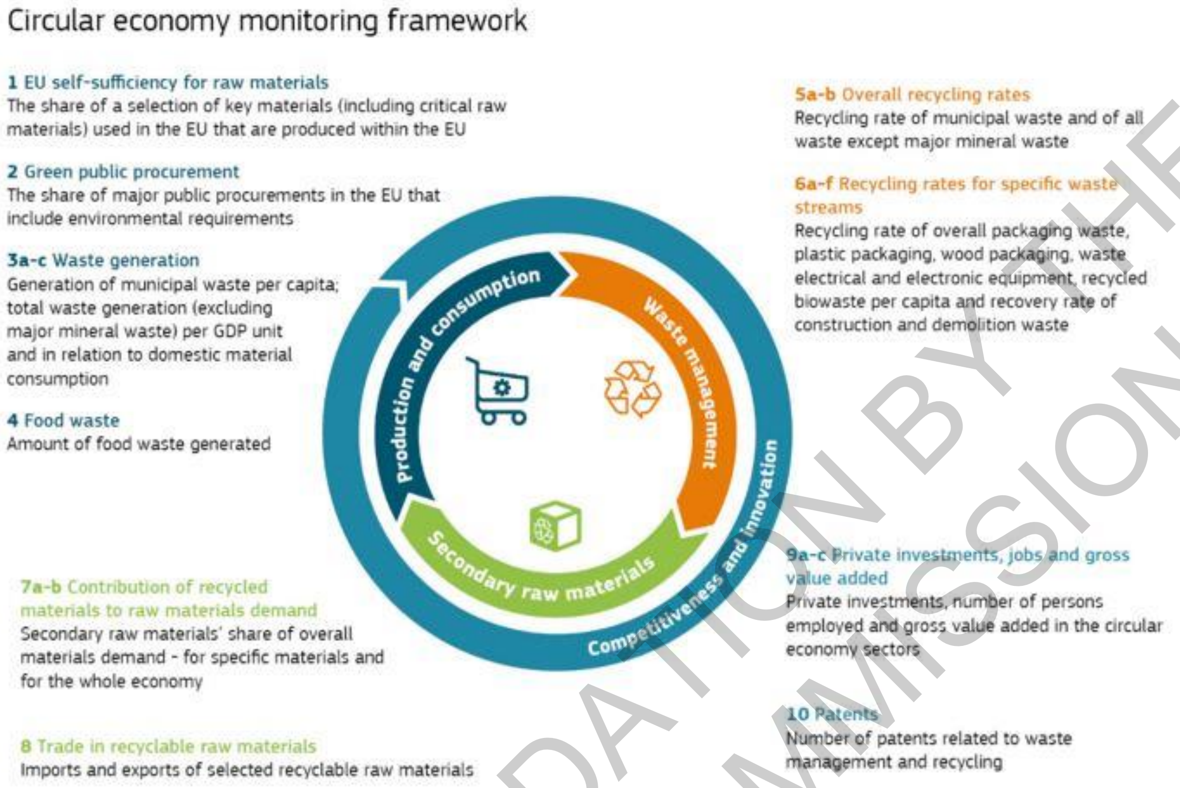
Supporting municipalities to monitor resource flows in line with impact targets and measurement processes



There are **several approaches** to measuring and monitoring resource flows. They can range from the simplest ones based on the collection of available **statistics**, to **modelling** techniques to generate new data, to the recompilation of data using new digital technologies, including hybrid approaches based on a combination of these. Similarly, flows and stock can be monitored at system (region or city) level or at company level. The first is generally based on **Multifactor analyses (MFA)** informing on the metabolism of the system as a whole, while the second, which is generally conducted through Activity-Based Spatial MFA, informs on the actors involved in the material flows and their exchanges.

In general, the flows monitored locally and generally available in public statistics concern **urban waste**, **energy**, **water** and, more sporadically, **biomass**, including **food waste**. Other types of flows (i.e. metal ores, construction material or material energy-carrier) require some sort of modelling. More recently, thanks to the advent of Industry 4.0 IT tools, examples of real-time monitoring can be found using sensors and IoT technology, including tool which automatically measure circular economy performance and identify areas of opportunity (see e.g. Circle City Scan Tool).

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Supporting municipalities to monitor resource flows in line with impact targets and measurement processes

Simplified model of circular economy materials and energy. Source: AEMA

Alongside the monitoring of resources during early stages to support the design of circular economy solution, the monitoring of resources should also be carried out constantly to evaluate the progress towards circular economy systems. For this, a **KPIs monitoring system** should be defined based on the identified flows and project objectives. In this regard, it is important to include both, relative and absolute indicators, e.g. total Municipal Solid Waste (MSW) and MSW/cap, as well as define how these relates to overarching sustainability frameworks (e.g. SDGs or Planetary boundaries).

CO-BENEFITS	Monitoring resource flows is key for an effective design of circular solutions. A comprehensive understanding of the urban metabolism favours the **optimal closure of material cycle**, as well as it ensures a better **waste and water management**. It can also contribute to **boosting local business (km 0)** and **proximity economy** by identifying potential opportunities between different local actors. Whilst not directly contributing to reduction of e.g. GHG emission, ecological footprint, energy needs, etc., **the definition of a monitoring framework including respective KPIs is an instrumental tool for a correct territorial planning**.
KEYWORDS	It is directly linked with other solutions such as Urban metabolism mapping (identifying product streams and material inputs) or Capacity building for city officials to understand urban metabolisms and circular solution opportunities.
EXTERNAL LINKS	• Circle Economy Scan: Do you want to make your city more circular? • OECD monitoring framework, urban studies • ESPON CIRTER, Circular Economy and Territorial Consequences: monitoring framework • Circular Cities and Regions Initiative (CCRI): CCRI Methodology (coming soon) • Repair project (H2020): http://h2020repair.eu/ • Indicators for Circular Economy (CE) transition in cities - Issues and mapping (Urban Agenda for the EC, Circular Economy)

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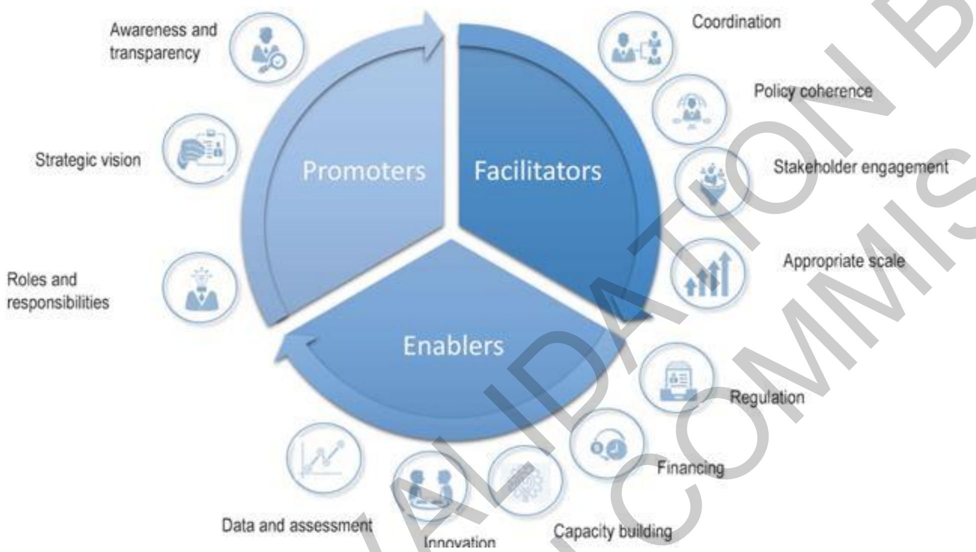
This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

3.8.6 Capacity building and engagement with municipalities to identify and co-create circular solutions and roadmaps

- Authors: **METABOLIC**
- Knowledge Repository link: https://netzerocities.app/resource-1548

Capacity building and engagement with municipalities to identify and co-create circular solutions and roadmaps

Transitioning cities toward fundamentally circular models require a broad range of expertise and activities.
To perform this generational journey, it is key that municipalities, not only receive adequate advice but also are taught new ways to comprehend their **urban metabolism**, plan their **journey**, and enact change within their **urban ecosystems**.



The governance of the circular economy in cities and regions: A Checklist for Action (OECD, The Circular Economy in Cities and Regions 2020)

Capacity building is the process of teaching cities how to use the right tools and frameworks to robustly analyse the current state of their cities and make evidence-based decisions to facilitate the implementation of circular solutions. The continuous engagement of municipal partners is also key to **develop a clear roadmap** that defines their **circular transition plan** for the coming years, spearheaded by goals that act as guide posts along the way. Capacity building here again plays a key role, as setting up quantifiable goals that can effectively be monitored often requires additional training and skills development across different municipal departments. Capacity building and engagement activities are most robust when aimed at gathering different stakeholder groups to enable the co-creation of the transition roadmap and the circular solutions within it.

By increasing municipalities' capacities with urban analysis, road-mapping, goal-setting, monitoring and co-creation processes, the transition of each city can be fast-tracked.

CO-BENEFITS	Capacity building and engagement activities have several co-benefits. By gathering different stakeholder groups, it **improves the access to information** and communication flows between various societal groups and within different municipal department. They also help **raise awareness** within municipality departments involved about the current linear system of their city and the transition necessary to transform it towards a net-zero and circular model. Training to **upgrade existing or learn new skills** is the main goal in capacity building initiatives. These new skills can help municipalities to make **better and more-informed resource management decisions** in their day-to-day activities. Finally, road-mapping helps define a clear overarching vision which may support **behaviour change** over the long-term towards this co-created and shared future.

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Capacity building and engagement with municipalities to identify and co-create circular solutions and roadmaps	
KEYWORDS	It is directly linked to other solutions such as Urban metabolism mapping (identifying product streams and material inputs) or Supporting municipalities to monitor resource flows in line with impact targets and measurement processes.
EXTERNAL LINKS	• Circular cities and regions initiative (Open call for Pilots and Fellows) • Roadmap Circular Resource Efficiency Management plan (EC, Urban Agenda for the EU) • OECD The Circular Economy in Cities and Regions, urban studies • UrbanWINS Toolkit Guidelines for the selection and implementation of adequate stakeholder engagement techniques

3.8.7 Capacity building for city officials to understand urban metabolisms and circular solution opportunities

- Authors: **Tecnalia**
- Knowledge Repository link: **https://netzerocities.app/resource-1568**

Capacity building for city officials to understand urban metabolisms and circular solution opportunities
Circular economy strategies and projects in cities are often based on experimentation and pilots. This is both an opportunity for creating new **knowledge and information**, but also a challenge in terms of the human and technical capital needed to design and implement circular economy **policies**. In this context, **capacity building** refers to the initiatives and activities aimed at adapting human and technical resources to the challenges to be met. **Training** can be related to technical issues for specific sectors, from agri-food to construction and demolition, or to the use of tools for enhancing the circular economy, from creating ad hoc strategies, to improving public procurement by considering circularity criteria. One way for local authorities to share knowledge and build capacities is through **city-to-city learning**, offered by dedicated networks. Reviewing and ensuring the required skills and capacities is a key aspect for developing an effective circular economy strategy.

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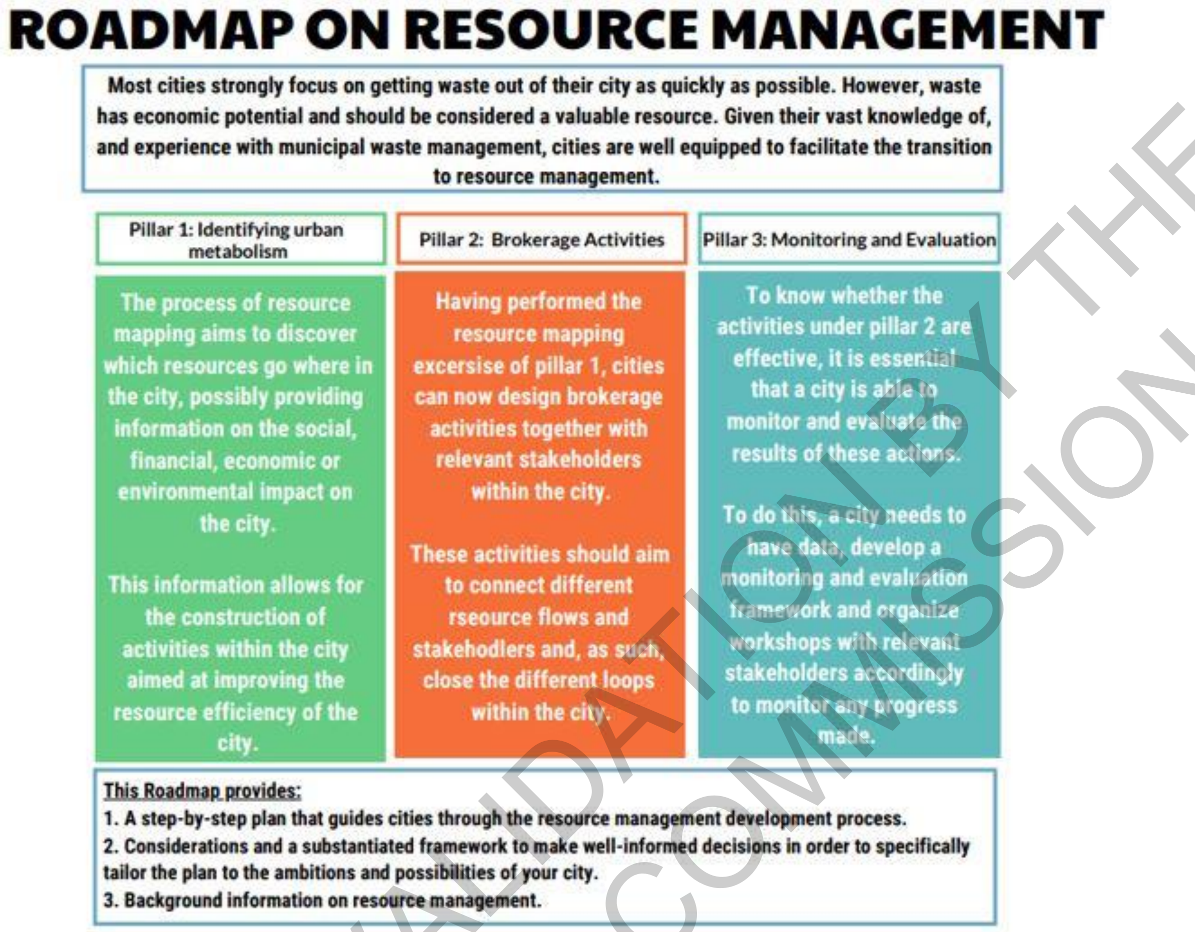
Capacity building for city officials to understand urban metabolisms and circular solution opportunities



Roadmap for a Circular Resource Efficiency Management. Source: EU Urban Agenda Partnership on Circular Economy

Skills and capacities may refer to:

- Setting a circular economy **strategy** that is realistic, result-oriented, tailored and coherent with national and regional objectives.
- **Coordinating** across different **levels of government**, ensuring complementarities and achieving economies of scale across boundaries.
- Engaging **stakeholders** in the planning process of circular economy strategy.
- Ensuring adequate **financial resources** by linking strategic plans to multi-annual budgets and to mobilise private sector financing.
- Collecting and analysing **data**, monitoring progress and carrying out evaluations.

The Roadmap for a Circular Resource Efficiency Management provided by the EU Urban Agenda Partnership on Circular Economy offers cities and urban areas a structured, step-by-step approach to develop a plan of action that improves resource efficiency and drives the transition to a circular economy, including guidance on how to conduct a urban metabolism assessment.

CO-BENEFITS	Besides being a key requisite for a successful deployment of any **circular solutions**, capacity building will provide several co-benefits directly connected with **social capacity building** and **increased skill development**. These will allow, in turn, for a **better management** of public activities/responsibilities such as **waste and water** management, **land use** management, **material cycle** optimization and **food waste reduction**. Raised awareness.
EXTERNAL LINKS	• European Circular Economy Stakeholder Platform (collection of initiatives and guidance on education & training) • OECD, The Circular Economy in Cities and Regions synthesis report

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<table>
<tr><th colspan="2">Capacity building for city officials to understand urban metabolisms and circular solution opportunities</th></tr>
<tr><td></td><td>Circular Cities and Regional Initiatives - Coordination and Support Office (coming soon)
Roadmap for a Circular Resource Efficiency in cities</td></tr>
</table>

3.8.8 Capacity building and training

- Authors: **Energy Cities**
- Knowledge Repository link: **https://netzerocities.app/resource-1578**

Capacity building and training

In the framework of their Sustainable Development Goal 17: **Revitalizing the Global Partnership for Sustainable Development**, the United Nations defines **capacity building** as "*the process of developing and strengthening the skills, instincts, abilities, processes and resources that organizations and communities need to survive, adapt, and thrive in a fast-changing world*".

Numerous **EU programmes and initiatives**, in all fields of economy and society, include capacity building and training components as one of their key success factors. This is of course also the case for programmes and initiatives in the fields of climate mitigation and adaptation, implemented at all levels of governance: European, national and local.

In the past decades, many studies and surveys have shown in a constant manner that European cities lack of internal capacities to implement their energy and climate projects and thus, to achieve their climate objectives and commitments. Their **main capacity building needs are in human resources and skills**, and in **financial expertise**, the first one being sometimes a barrier for some cities to access EU funding.

Source: Piqsels.com Public domain

This can be improved by the **participation of civil servants to long-life learning programmes** accessible in their country, as well as by their participation to EU twinning and peer-to-peer learning programmes, like the Covenant of Mayors Europe's peer-learning programme, the ManagEnergy' masterclasses and expert missions, or the H2020 PROSPECT+ capacity-building programme on innovative financing. Another noteworthy initiative in the field is the creation of the Civil Servant Exchange Programme (CSEP), proposed by students of the College of Europe in the framework of the European Citizens' Initiative.

As for capacity-building on **financing**, the EU has also developed a number of facilities to finance legal, technical and financial support for large-scale projects, among which: the Sustainable Energy Investment Forum, the InvestEU Advisory Hub, the European Local Energy Assistance (ELENA) or the European City Facility (EUCF).

CO-BENEFITS	Increased skill development.

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Capacity building and training	
EXTERNAL LINKS	• EU facilities on Capacity building and technical assistance for energy efficiency • Integrated capacity building for urban governance, planning and management (URBANET), Patrick Wakely, July 2016 • Covenant of Mayors in Europe' peer-learning programme • ManagEnergy initiative • H2020 PROSPECT+, a capacity-building programme on innovative financing for EU regions and cities • European Citizens' Initiative proposal for the creation of a Civil Servant Exchange Programme

3.8.9 Educational/ Capacity building barriers identification

- Authors: **REGEA**
- Knowledge Repository link: **https://netzerocities.app/resource-1588**

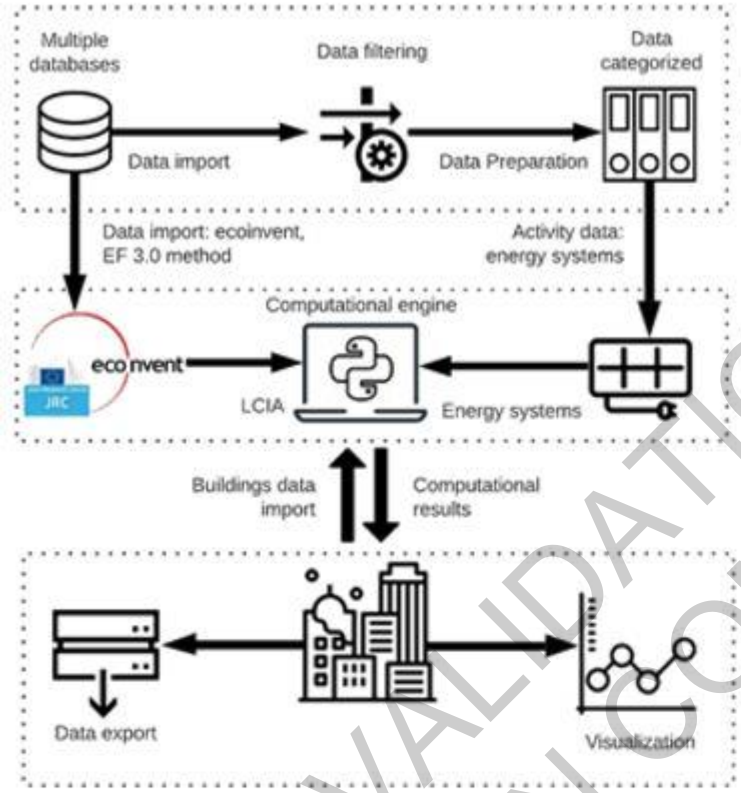
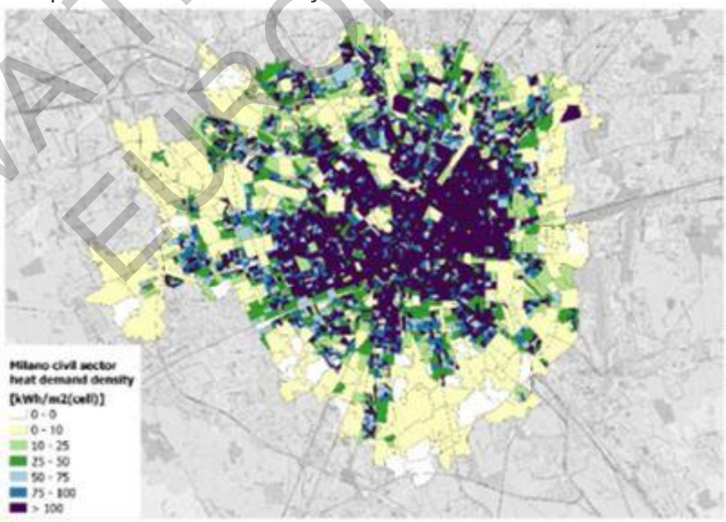
Educational/ Capacity building barriers identification	
Energy transition commitments and policies mean people qualified to work in the sector and its supply chains will continue to be in great demand. The **barriers** in the educational system in terms of the energy transition are that education and training systems are reactive and require time to adapt since the design and implementation of updated and new courses or programmes is a complex task. Because of the fast upgrade of the technologies, the most recent potential, production and consumption data can be difficult to obtain, or of poor quality which causes a lack of information on the socio-economic benefits of the energy transition. For some technologies lack of standards damages their reputation and lowers the possibilities of implementation. Although nowadays everyone knows about the benefits of renewable energy sources and energy efficiency, a **low level of awareness** remains in some parts of the population, especially its residential use, where people are not interested in learning more about them. Finally, there are some **socio-cultural barriers** such as public expectations of cheap and abundant electricity and aesthetic and environmental concerns.	
CO-BENEFITS	By surpassing the educational/capacity-building barriers **access to information** will be improved, **awareness/behavioural change** will be raised and **skills development** increased which will improve **access to job opportunities**.
KEYWORDS	It is directly linked to other solutions such as qualification programmes, trainings, educational activities on NBS, or, more in general: capacity building and training, user engagement for energy efficiency.
EXTERNAL LINKS	• Capacity Building strategic Framework for IRENA (International Renewable Energy Agency) • Renewable Energy and Jobs (IRENA: International Renewable Energy Agency)

3.8.10 Urban-scale environmental decision support system (DSS) based on EPC (Energy Performance Certificate) databases

- Authors: **POLIMI**
- Knowledge Repository link: **https://netzerocities.app/resource-1598**

AWAITING VALIDATION BY THE EUROPEAN COMMISSION

This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

Urban-scale environmental decision support system (DSS) based on EPC (Energy Performance Certificate) databases
There is a noticeable potential to process **Energy Performance Certificate (EPCs)** to evaluate the environmental performance of the building sector at the city scale. Such assessment requires an **open-access database** and a **standard level of EPC** information reported by cities. Although a review on the availability of EPC databases revealed that several European cities currently report EPC databases, only a few have already provided a public open-access database (see external links section for further information).  Environmental Decision Support System engine Given the possibility of providing open access EPC databases as a tangible solution, the use of open data from the EPCs can lead to develop an **Environmental Decision Support System (EDSS) tool**, which helps in the measurement of potential environmental impacts of the buildings during different phases (e.g. operational phase), or the assessment of several environmental impact categories in compliance with the Life Cycle Assessment standards.  Civil sector heat demand density in each census cell [kWhth/m2 year (cell)]

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Urban-scale environmental decision support system (DSS) based on EPC (Energy Performance Certificate) databases	
CO-BENEFITS	**Reduce GHG emissions**, reduce risk to natural and climate hazards, green awareness, reduce ecological footprint, **integrated planning**, better planning, more secured investments.
KEYWORDS	EPC databases: • Italy: https://siape.enea.it/indici-prestazione-emissioni • Italy - CENED: http://www.cened.it/opendata_cenedplus2 • Denmark: https://sparenergi.dk/forbruger/vaerktoejer/find-dit-energimaerke • Netherlands: https://www.ep-online.nl/PublicData • Spain: https://analisi.transparenciacatalunya.cat/Energia/Certificats-d-efici-ncia-energ-tica-d-edificis/j6ii-t3w • France: https://www.data.gouv.fr/fr/datasets/diagnostics-de-performance-energetique-pour-les-logements-par-habitation/#resources • Ireland: https://ndber.seai.ie/BERResearchTool/ber/search.aspx
EXTERNAL LINKS	The RELAB group of the Department of Energy – Politecnico di Milano, using open data of the Energy Performance Certificates (EPCs) published in open access in CENED database for Lombardy Region – Northern Italy developed an **Environmental Decision Support System (EDSS) tool**. The EDSS aims to support the **city of Milan** in measuring the potential environmental impacts of the buildings during the operational phase. The tool permits the assessment of several environmental impact categories (beyond carbon dioxide equivalent) in compliance with Life Cycle Assessment standards. The elaboration of the data statistically allows the evaluation of the geographical distribution of the heat demand and the implementation of environmental benchmarks at the district scale. It facilitates the proposal of solutions for building retrofitting and opportunities for developing a 4th generation district heating network; these solutions aim to help the city reach the decarbonization targets. The EDSS model, which is already tested and verified in the Lombardy Region (Italy), can be replicated in various European cities to help and inform cities' policy-makers for urban-scale regeneration with an energy and environmental perspective. The EDSS can potentially be calibrated and applied to other European cities as described in the two following scientific publications: • Famiglietti et al. (2022) - https://www.sciencedirect.com/science/article/pii/S0196890422001856 • Pozzi et al. (2021) - https://www.sciencedirect.com/science/article/pii/S2352484721006855

3.8.11 Engagement, co-creation and co-design of NBS and Green Infrastructure plans and interventions

- Authors: **LGI**
- Knowledge Repository link: **https://netzerocities.app/resource-1608**

Engagement, co-creation and co-design of NBS and Green Infrastructure plans and interventions
Those solutions aim at **bringing together concrete experiences**, different know-hows, views and approaches to design, between different actors, infrastructure plans and solutions using **NBS**. Involving different actors together entails a **wider spectrum** when considering methodologies, implementation plans and outcomes predictions. This can be done through a share of interests, needs, examples, skills and technical capabilities. Often these processes encompass **social learning, and community participatory processes**.

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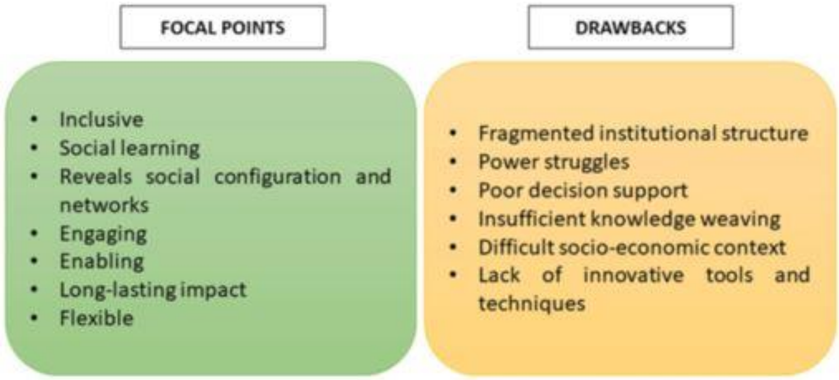
<table>
<tr><th colspan="2">Engagement, co-creation and co-design of NBS and Green Infrastructure plans and interventions</th></tr>
<tr><td colspan="2">


Focal points and drawbacks of a co-design process to address NBS for inclusive urban planning. Source: "Co-design Processes to Address Nature-Based Solutions and Ecosystem Services Demands", Sustainable Cities, 2020.

Benefit: A wider spectrum of actors and contexts co-participating in decision making processes and infrastructural planning can insure a more comprehensive, fair, and equal project, if conflicts of interest are overcome.

It can be implemented in any context interested in applying NBS solutions to its territory.</td></tr>
<tr><td>**CO-BENEFITS**</td><td>
• **Climate Adaptation**
• **Climate Mitigation**
• Enhancing **citizen participation**, connectivity, and community
• Increased **skill development**
• Improve land use management
• Improve soil health
• **Reduce hot spots/urban heat islands** in the city and improved air quality: nature, by absorbing CO2 emissions and providing shadow cool air, increases air quality and reducing the heat island effect
• Greater **Biodiversity** (species increase, pollinator increase, increases green awareness, ecological connectivity, reduces risk of epidemics, ecological footprint)
• Enhance attractiveness of the cities
• Healthier and more attractive lifestyles
• Better physical activity of individuals
• Better access to living areas for all</td></tr>
<tr><td>**EXTERNAL LINKS**</td><td>
• Co-design Processes to Address Nature-Based Solutions and Ecosystem Services Demands: The Long and Winding Road Towards Inclusive Urban Planning - Sustainable Cities (CLEARING HOUSE project)
• Planning and governing nature-based solutions in river landscapes: Concepts, cases, and insights - NCBI
• Co-creation Pathway for Urban Nature-Based Solutions: Testing a Shared-Governance Approach in Three Cities and Nine Action Labs - CLEVER Cities project</td></tr>
</table>

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3.8.12 City coaching in NBS

- Authors: **LGI**
- Knowledge Repository link: **https://netzerocities.app/resource-1618**

This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

City coaching in NBS	
City coaching is a type of non-technical intervention performed by an advisory body for members of a city's administration or city officials. This type of intervention can take the form of a **meeting**, a **webinar**, a **workshop**, or a **training course** lasting for a determined time, depending on the city's needs.   The objective of **city coaching on NBS** is to develop the **awareness, know-how and reflexes** of participants regarding the benefits and challenges of adopting and implementing NBS. The teaching approach can be based on a combination of case study, discussions, serious games, field visits, lectures, and reading.	
CO-BENEFITS	Improved access to information, raised awareness, behavioural change, increased skill development.
EXTERNAL LINKS	• City coaching (in NBS) - URBAN GreenUP project • Non-technical interventions (in NBS) - URBAN GreenUP project

3.8.13 Platform for Enhancing Multi Stakeholder Dialogue to Implement NBS across EU

- Authors: **LGI**
- Knowledge Repository link: **https://netzerocities.app/resource-1628**

Platform for Enhancing Multi Stakeholder Dialogue to Implement NBS across EU	
A **multi-stakeholder communication platform** supporting the understanding and promotion of Nature-based Solutions (**NBS**) throughout Europe. The platform aims at supporting a continuous **dialogue & interaction on NBS** to: • steer dialogue through forums and debates; • identify, communicate & promote successful NBS; • identify regulatory, economic & technical barriers; • foster collaboration at local, regional, national & EU levels; • develop synergy with other projects on NBS.	
CO-BENEFITS	Sharing economy, Improved access to information, raised awareness/behavioural change, green awareness.
EXTERNAL LINKS	• ThinkNature Project on Nature-based Solutions VIDEO • ThinkNature Platform (A multi-stakeholder communication platform supporting the understanding and promotion of Nature based Solutions)

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This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

3.8.14 Gender diversity considerations in urban mobility

- Authors: **EIT-UM**
- Knowledge Repository link: **https://netzerocities.app/resource-1638**

Gender diversity considerations in urban mobility

The integration of **gender diversity considerations** in **urban design** and **mobility planning** can help to create more inclusive cities and increase agency of marginalized groups and gender minorities. Gender differences can result in different mobility patterns that can be explained by the structural gender inequality that persists in our daily lives. Women typically travel shorter distances than men and use mobility modes such as walking, cycling and public transport more often.

Source: https://pixnio.com/sport/biking-sport/women-active-lifestyle-fitness-wheel-cyclist-road-exercise-bicycle#

Based on **gender differences, the mobility challenges** may also vary. For example, women's concerns about safety and physical accessibility prevail as two of the main challenges for women's daily use of active and public transport. These challenges are often overlooked in **urban and transport planning** but can be addressed by including a **gender approach** that takes into account women's requirements and perceptions of their daily mobility experience. This can be achieved by using **gender disaggregated data** (e.g. about perceptions of safety in public space and on public transport) to inform the planning process, the design of policies from a gender perspective, evaluation of urban mobility policies based on gender differences, training and mainstreaming awareness, and the use of digital solutions to evaluate transport networks from a gender perspective.

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This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

Gender diversity considerations in urban mobility

Gender differences by modal split in the EU-27

	Car	Public Transport	Walking	Bicycle	Motorcycle	Other
EU 27	**51.4**	**20.6**	**14.7**	**8.7**	**1.8**	**2.7**
Men	57.5	18.0	10.2	8.3	3.3	2.7
Women	45.8	23.1	18.8	9.1	0.5	2.7

Source: Eurobarometer "Attitudes on issues related to EU transport policy", 2007

Gender differences by modal split (value %) in different Member States

	Italy, 2011		UK, 2010		Germany, 2008		France, 2008	
Transport mode	**Women**	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**	**Men**
Car	60.6	72.7	37.5	47.2	36.3	49.2	62.8	67
Car as passenger			26.7	17.4	18.8	11.3		
Public transport	16.5	12.7	10.3	9.8	8.8	8.2	8.5	8.1
Foot&Byke	22.9	14.6	23.6	23.2	36.1	31.3	28.1	21.7
Other			1.9	2.4			0.6	3.2
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Source: Isfort, 2011; UK National Travel Survey 2010; Bundesministerium fuer Verkehr, Bau und Stadtentwicklung, 2008; Ministère de l'Écologie, du Développement Durable et de l'Énergie, 2008

Case studies as highlighted in the Handbook for Gender-Inclusive Urban Planning and Design published by the World Bank show that better representation and increasing participation and visibility of women and gender minorities in the planning processes can help create safer and more accessible public spaces as well as foster innovative solutions that all citizens can benefit from.

Addressing gender aspects can play a **key role in promoting low and zero-emission mobility**. For example, by responding to specific gender-related needs and safety concerns, the use of active mobility and public transport can be increased.

CO-BENEFITS

Incorporating a gender perspective in urban mobility (in both active mobility and public transport) will foster **social cohesion** since it provides more inclusive public services and public spaces. Identifying the barriers/deterrents of women using active transport will help in planning and designing a more attractive mobility infrastructure and to incentivize active mobility, therefore **reducing GHG emissions**, fostering better **physical activity of individuals** and **better access to living areas** as well as promoting a healthier and more attractive lifestyles. Including specific trainings on gender perspective in urban mobility will lead to a **skill development increase of professionals** (from public and private companies) and will help **raising awareness** of the role of women in urban mobility. Increased participation and representation of women and gender minorities can also **enhance citizen participation**, connectivity and community.

EXTERNAL LINKS

- Handbook for Gender-Inclusive Urban Planning and Design (World Bank)
- Gender Mainstreaming: Creating inclusive mobility - POLIS Network
- Gender equality and mobility: mind the gap! (CIVITAS initiative)
- Gender Equality and Sustainable Infrastructure (OECD)
- A Union of Equality: Gender Equality Strategy 2020-2025 (EC)

EXAMPLES

- A Gender Perspective in Urban Mobility: Barcelona's plan for justice 2016-2020 (WOMEN4CLIMATE)

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This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

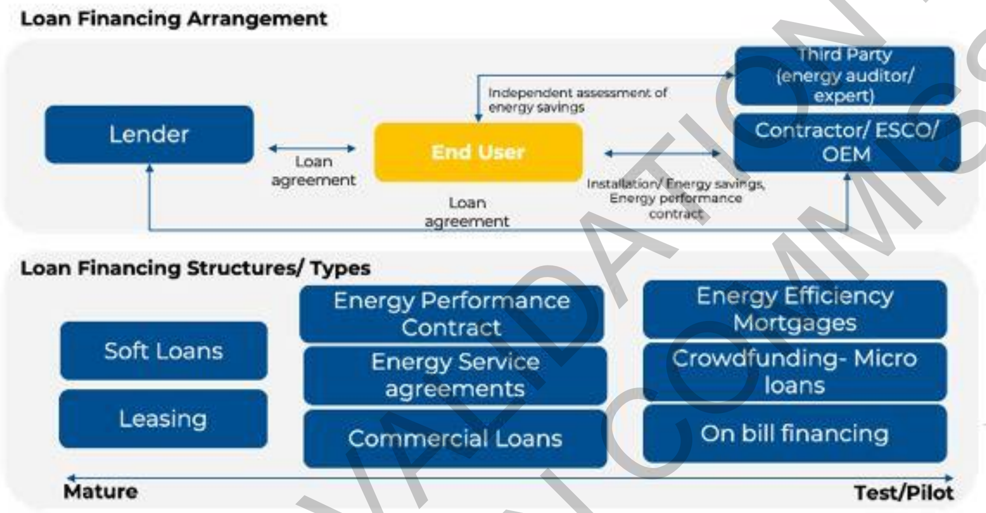
3.8.15 Loans for Energy Efficiency (EE)

- Authors: **South Pole**
- Knowledge Repository link: https://netzerocities.app/resource-1648

Loans for Energy Efficiency (EE)

Collectively, **buildings in the EU are responsible for 40% of energy consumption** and 36% of greenhouse gas (GHG) emissions, which mainly stem from the construction, usage, renovation and demolition. Approximately **three quarters of building stock is energy inefficient**. (European Commission, 2020).

"Financing" EE investments is a key barrier towards wide scale adoption of EE solutions for both new and existing buildings. **"Loan financing"** can be a key instrument towards enabling such investments across public, private and community buildings. Loan financing can be offered by vendors, equipment manufacturers, energy services companies or third-parties such as banks or financial institutions.



The **type and structure of loan** may vary depending on the potential savings achieved from the investments and the profile of the borrower. While **structured development loans** can be an effective tool for financing public buildings, **commercial loans** at competitive prices could enable financing for commercial buildings, and **soft loans** can enable adoption of EE measures for community buildings.

Similarly, **underwriting energy savings** when purchasing or refinancing a property, allows for the financing of efficiency upgrades with mortgage capital for new buildings. Hence, access to loan financing at competitive rates can be a key enabler of adopting EE measures in the built environment at scale and progressing towards Net Zero Energy Buildings, thereby reducing emissions from the built environment and improving energy access.

CO-BENEFITS	• Climate mitigation: on account of **reduction of GHG emissions**; • Reducing energy needs: by **financing EE** interventions; • **Increasing access to clean and affordable energy**: by enabling financing of EE measures, decarbonisation of heating and cooling boost local businesses; • Generating demand for contractors and equipment at scale; • Decreased future energy costs: on account of EE, **energy access at affordable prices**; • **Energy-independence**: Reducing the dependence on fossil fuels-based energy and hence energy imports.
EXTERNAL LINKS	• Energy Efficiency in Buildings (EC) • Finance your sustainable and climate action - Experience from 195 public authorities in your hands for learning and replication (PROSPECT project)

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This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

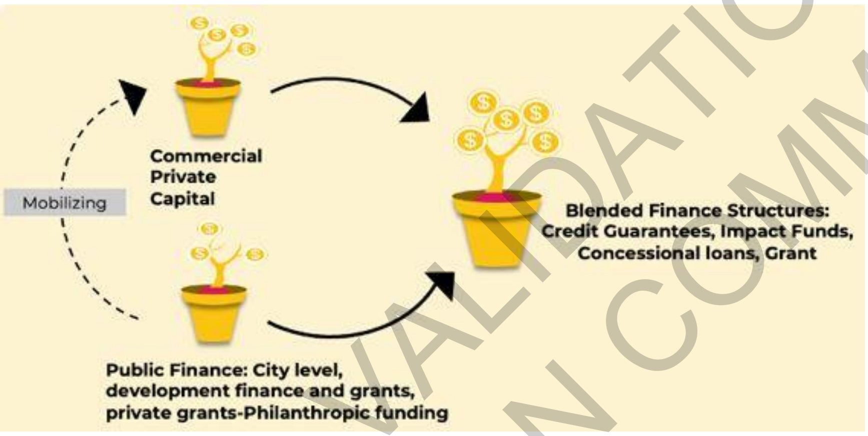
3.8.16 Blended finance for Energy Efficiency (EE)

- Authors: **South Pole**
- Knowledge Repository link: https://netzerocities.app/resource-1658

Blended finance for Energy Efficiency (EE)

The built environment is responsible for ~40% of the EU's carbon emissions (European Commission, 2020). **Significant investments are required to implement demand-side**, **passive**, as well as **infrastructure-level energy efficiency (EE) measures** to reduce these emissions in line with the global temperature rise. While traditional financing is available for new commercial energy efficient buildings, financing additional investments for EE measures in new community buildings –such as affordable group housing and renovation of existing community buildings– is a key challenge.

Blended finance can be an effective solution to address this gap, by **blending public, philanthropic, grant and development finance** with mobilised private capital can enable the achievement of financing at scale for such projects. **Innovative financing instruments** –such as energy saving guarantees, credit guarantees, impact funds, concessional loans, performance-based grants, carbon finance coupled with city level policies– can become an effective instrument for financing EE interventions which would otherwise not be financed through traditional financing.



Blended finance can be used to **support financing a range of interventions**, such as **deep renovation**. Renewable energy-based cooling and heating systems, or individual adoption of thermal improvement interventions such as energy efficient lighting fixtures or upfront financing for EE interventions in new community buildings. The **benefits** of blended finance include **addressing energy poverty**, supporting the renovative wave objective of EU, reducing energy led GHG emissions, acting as a platform for local community, reducing energy bills and increasing awareness as well as supporting energy independence.

CO-BENEFITS	• Climate mitigation: on account of **reduction of GHG emissions**; • Reduced energy needs: by **financing EE interventions**; • **Increased access to clean and affordable energy**: enabling financing of RE measures and the decarbonisation of heating and cooling boost local businesses; • Generating demand of contractors and equipment at scale, decreased future energy costs: on account of **EE energy access at affordable prices**, health and **well-being**, temperature and **air quality**; • **Energy-independence**: reducing the dependence on fossil fuels-based energy and hence energy imports.
KEYWORDS	It has direct link with solutions such as demand management, passive energy efficiency measures; and more indirect connection with turnkey renovation, one-stop-shop for building renovation, user engagement for energy performance improvement, and other schemes to stimulate EE.

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Blended finance for Energy Efficiency (EE)	
EXTERNAL LINKS	• White Paper: How blended finance can catalyse building renovation (Climate KIC) • Report Release: An Integrative Business Model for Net Zero Energy Districts (RMI) • Innovations in Blended Finance: A Summary (GEF: Global Environment Facility) • Renovation wave Europe (EC)

3.8.17 Road/ Congestion pricing in transport

- Authors: **CEREMA**
- Knowledge Repository link: **https://netzerocities.app/resource-1668**

Road/ Congestion pricing in transport

Congestion pricing is a **transport demand management measure** adopted to reduce the impacts of traffic congestion on cities. It links the externalities of road transport directly to the travellers who produce them. They are implemented through the definition of **tolling systems** to influence short-term demand choices, forcing travellers to switch to sustainable transport modes and low impact road routes.

Congestion charges can be introduced either in a defined **geographical area or on a road network**, leading to two types of charging: area and network. The former can lead to two configurations of tolls, the zone toll and the cordon toll. In the first, the motorist pays a fixed rate to drive in the zone, regardless of the route. In the latter, a number of points delimit the toll zone. Each crossing of these points triggers a payment. In network pricing, the motorist pays to use a facility.

ERP Gantry at North Bridge Road, next to PARCO Bugis Junction

While reducing congestion is one of the objectives that congestion charging can help to achieve by regulating urban car traffic, it can **achieve other objectives**, which may or may not be cumulative:

- **generate revenue**: here they have a function of financing transport systems,
- improve the **quality of urban life** and in particular **air quality**: they have a function of reducing environmental nuisance.

An **urban toll** is defined by its numerous application methods: the perimeter chosen, the basis and levels of the tariff, the pricing hours, the detection and recognition systems, the payment methods, etc. Thus, depending on the political priorities, the choices, the methods of the toll vary greatly. In the case of a congestion toll, the authority tends to set the highest possible tariff (modulated according to the hours and days of traffic) in order to limit access to the chosen zone through prices. The focus here is

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Road/ Congestion pricing in transport	
on time savings and regularity. In the case of an infrastructure toll, the tariff is set in such a way as to obtain the maximum revenue to cover the investment while seeking to minimise the costs of the system adopted for the toll. It should be noted that this type of toll does not necessarily lead to a reduction in traffic. An environmental regulation toll, on the other hand, is aimed more at reducing the number of kilometres travelled by favouring distance-based pricing to reduce environmental impacts and transferring the revenue generated to public transport and modes such as walking and cycling. In addition, modulation by type of vehicle according to "Euro" pollution standards is possible. In this configuration, the most polluting vehicles are taxed more. Finally, there is another type of toll, **positive or reverse tolls**. These consist of encouraging motorists who travel on major roads during peak hours to use another mode of transport or to postpone their journeys to other times. In return, motorists are financially rewarded. In its objectives, this type of toll is similar to congestion charging.	
CO-BENEFITS	Road/Congestion pricing, by seeking to limit congestion, can contribute to reduce GHG emissions, reduce energy needs, improve air quality, reduce noise pollution and reduction of road danger. Beyond congestion, road/congestion pricing can have effects on transport demand, on modal shift, in particular towards cycling, walking and public transport, on pollutant emissions and thus contribute to a **better physical activity of individuals** and **healthier and more attractive lifestyles**. In fine, road/congestion pricing can lead to **enhance attractiveness of the cities** and **social cohesion** (gender, minority groups) even if for social cohesion, the pricing conditions are a point of vigilance.
EXTERNAL LINKS	• International Transport Forum: https://www.itf-oecd.org • Revisiting the Cost of the Stockholm Congestion Charging System • Decisive factors for the acceptability of congestion pricing (Centre for Transport Studies, Stockholm)

3.8.18 Integrated land use and urban planning with energy and climate

- Authors: **REGEA**
- Knowledge Repository link: **https://netzerocities.app/resource-1678**

Integrated land use and urban planning with energy and climate	
Spatial planning is a powerful tool municipalities, cities and region have with which they can define and enforce the development of infrastructure, real estate and services within their borders. It is inherently an **interdisciplinary** practice; however, it is often limited to the definition of zones and land use types without considering the full picture of the needs and goals locally and nationally. The **integration of energy and climate** with spatial planning can enable local and regional governments to both develop, implement and enforce their vision and integrate local, regional and national plans and strategies into a coherent and **holistic development plan**. This practice is being used in some European cities and regions but it is not fully regulated or recognised at national or EU levels.	
CO-BENEFITS	Spatial planning can integrate all aspects of a cities or regions development and can therefore positively impact most areas of energy, climate and mobility alongside physical development. This can include impacts to **reduce risk to natural and climate hazards**, enhance stability of the urban infrastructure, **reduce GHG emissions, reduce energy needs**, increased carbon sequestration capacity (explaining that this through

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Integrated land use and urban planning with energy and climate	
	indirect solutions such as NBS), better **waste management**, **improve air quality**, reduce noise pollution, **reduce hot spots/urban heat islands** in the city and so on.

3.8.19 Integrated land use planning and urban space management with mobility planning

- Authors: **Rupprecht**
- Knowledge Repository link: https://netzerocities.app/resource-1688

Integrated land use planning and urban space management with mobility planning
The **integration of land use planning and urban space management with mobility planning** is a central strategy to reduce and avoid vehicle miles traveled and to shift motorised trips to zero or low carbon modes of travel. The development of housing and businesses should be oriented towards infrastructure and services for walking, cycling and public transport.  Each carbon-free city needs an integrated approach for **land-use and transport planning** to create multimodal, inclusive, liveable and economically competitive urban areas in the long term.

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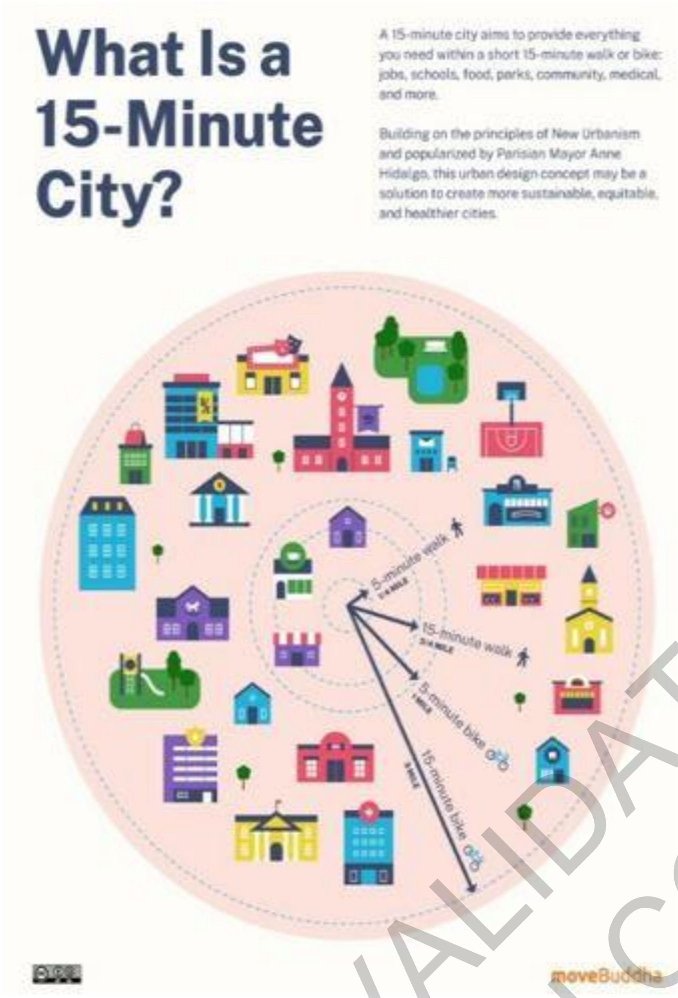
Integrated land use planning and urban space management with mobility planning



At city level land-use planning can influence the **density and location of housing**, promoting new buildings or businesses easily accessible by sustainable modes (incl. public transport and active mobility) in the present or in the future. New developments take place on brownfields and should have access to public transport. Promote mixed-used development to reduce distances people need to travel to use residential, commercial or business land.

At the neighbourhood level inter-modal hubs could combine collective mobility with active modes of travel. In addition to that, the creation of co-working spaces at hubs could reduce the number of commuters.

At street/square level urban space (e.g. parking space) could be reallocated to sustainable modes and for the use of the public such as green spaces, benches, shade and water points, and public toilets.

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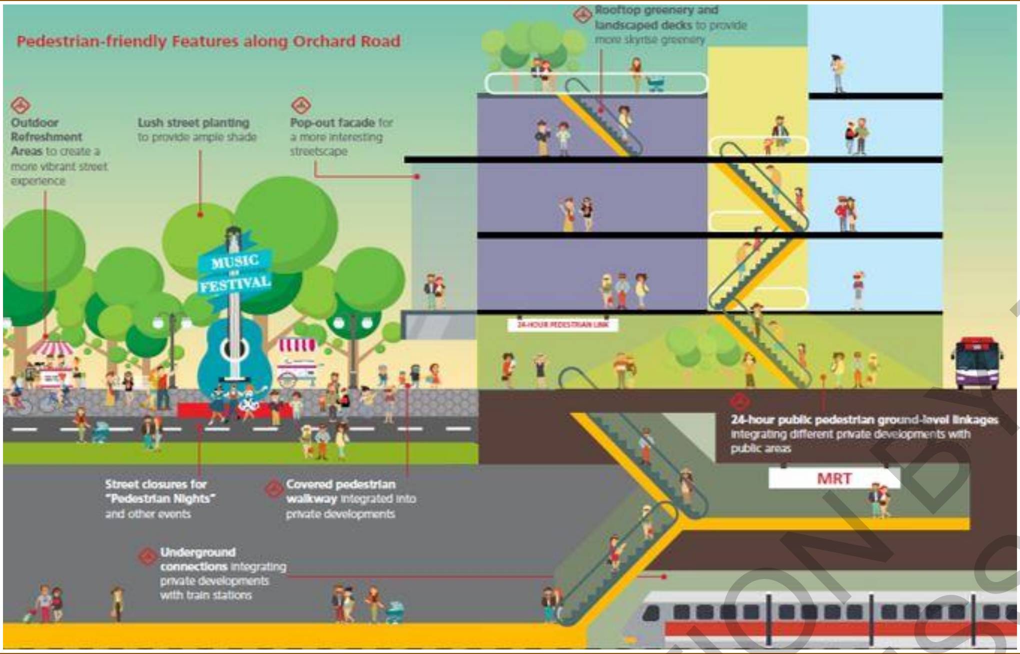
Integrated land use planning and urban space management with mobility planning



CO-BENEFITS	Urban planning more focused on accessibility, density and multimodality could **boost local business** and **social cohesion** through better access to living areas for all. With a more user needs-centric space management the **attractiveness of the city** increases through **improved air quality** and **less noise pollution**. In addition to that, the stability of the infrastructure could be improved if urban space becomes **greener** and allows for water management.
KEYWORDS	It is directly linked to other Mobility and Transport solutions, such as SUMPs, Fostering walking, Fostering cycling, Parking policies, management and fees. You can also check the 15-minute city concept.
EXTERNAL LINKS	• Policy Brief: How to build successful cities: strengthening the integration between land-use and mobility planning (UN Habitat) • Streetscape Guidance (Transport for London) • Liveable Streets: Connecting People + Places • A Tactical Urbanism Guidebook (SUTP: Sustainable Urban Transport Project) • A Handbook on Sustainable Urban Mobility and Spatial Planning: Promoting Active Mobility (UNECE) • The 15-Minute City (Transformative Mobility)

3.8.20 Integrated climate plans for cities (i.e. SECAPs)

- Authors: **Tecnalia**
- Knowledge Repository link: **https://netzerocities.app/resource-1698**

Integrated climate plans for cities (i.e. SECAPs)
Integrated climate plans are the result of a well-coordinated strategic local process that generates a binding document, together with the local community. They show the path towards a meaningful and effective implementation of climate action in the city within a certain period of time. In this sense, an integrated climate plan must be one of first steps a city needs to take towards a carbon neutrality goal, structuring and aligning potential initiatives, resources, and decisions through a strategic document, reaching the widest local consensus possible.

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Integrated climate plans for cities (i.e. SECAPs)

The fight for climate action in cities is built upon two main fields. **Climate change mitigation** refers to the reduction and prevention of GHG emissions, whilst **climate change adaptation** intends to prepare for the potential impacts of a warming world.

In this sense, the Covenant of Mayors for Energy & Climate **(CoM)** is the initiative that gathers more members interested on advancing towards climate-neutrality. With 10.898 signatories from 54 different countries and 6.221 submitted action plans, the CoM has become the main-stream initiative for cities' climate change mitigation and adaptation. Since 2015, both mitigation and adaptation dimensions are addressed by an integrated framework under the format of **Sustainable Energy and Climate Action Plans (SECAPs)**. SECAPs connect cities' emission reduction commitments with the measures the city plans to implement and the progress is regularly monitored using a common reporting method.

To cope with mitigation and adaptation as well as other urban challenges, urban planning has been incorporating diverse city systems to its practice since 19th century, where the need of a coordinated overall planning perspective is key to appropriately address those evolving urban challenges. This, together with a transversal participation of **local stakeholders**, is the root of the so-called "integrated planning" concept. Accordingly, a good SECAP would have to address both mitigation and adaptation challenges from an integrated urban planning perspective.

CO-BENEFITS	Some of the co-benefits are: • Reduce risk to natural and climate hazards • Enhance stability of the urban infrastructure • Reduce GHG emissions • Reduce energy needs • Increased carbon sequestration capacity • Raised awareness/ behavioural change • Improve air quality • Reduce hot spots/urban heat islands in the city
KEYWORDS	SECAP can be directly linked to solutions such as: Integrated urban planning, Governance EU climate Neutrality framework (NECP, LTS, LTRS, CEAP), GHG scenario modelling.
EXTERNAL LINKS	• Covenant of Mayors for Climate & Energy. Plans & Actions • Guidebook "How to develop a SECAP" (JRC)

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3.8.21 Sustainable Urban Mobility Plan (SUMP)

❖ Authors: **Rupprecht, CEREMA**

- Knowledge Repository link: https://netzerocities.app/resource-1708

Sustainable Urban Mobility Plan (SUMP)

A **Sustainable Urban Mobility Plan (SUMP)** is one of the main instruments used worldwide by public administrations to plan mobility systems in an integrated way, looking at environmental and climate change aspects. Following the EU endeavours to cut emissions from the transport sector by at least 55% by 2030 and by 90% by 2050, all European competitive cities are currently looking into developing or updating a SUMP strategy.

A SUMP combines technical planning with the social-political dimension and builds on relevant sector plans, e.g. urban development plan or climate plan. This comprehensive and overarching type of process and document is thus laying the foundation for future and green investments in the mobility sector in the city. Beyond that, SUMP is also supposed to cover the **Functional Urban Area (FUA)**. This **regional approach** is of great importance for a better and more sustainable organisation of interurban transport flows of passengers and freight.

Figure 1: The 12 Steps of Sustainable Urban Mobility Planning (2nd Edition) – A decision maker's overview

The SUMP establishes horizontal and vertical cross-departmental working structures and provides a highly accepted and evidence-based work programme, which should build the foundation for a **mobility transformation** towards improved accessibility and quality of life through a **shift towards sustainable mobility**. This requires a thorough assessment of the status quo and future trends, a common vision, strategic objectives, and an integrated set of short-, medium- and long-term measures from different policy areas, including regulation, promotion, financing, technology and infrastructure.

In contrast to traditional master planning approaches, the SUMP concept emphasises **stakeholder cooperation, public-private partnerships**, and **mobility vision co-creation** together with **citizens**. As an important component SUMP includes scenario building (e.g. zero-emission scenarios) and strives for thorough monitoring and evaluation of the measure implementation process and the evaluation of the achievements along with SMART targets.

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This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

Sustainable Urban Mobility Plan (SUMP)	
An excellent package of guiding documents is available from www.eltis.org and is constantly being adapted and aligned to wider EU policies (Green Deal, Urban Mobility Framework, Efficient and Green Mobility Package).	
CO-BENEFITS	The SUMP co-benefits are spanning from **increased climate resilience** and actions towards climate mitigation, to **increase public health** and the **quality of life** in a city or functional urban area. The SUMP process will eventually lead to an **enhanced attractiveness for investors** due to a better inter and intra-urban connectivity, which has important **economic and social impacts**: boosts local economy and proximity economy, increases employment rate and number of jobs. Due to its participatory characteristic, the SUMP process contributes to **enhancing citizen participation** in the public decision process and thus awareness building. The SUMP promotes **mobility behavioural change** towards a healthier and more attractive lifestyle, thus contributing to a **better public health** by increased physical activity of individuals. Moreover, a better mobility system provides conditions for **better accessibility to living areas** for all citizens, and contributes to land use policy development and thus to an improved land use management. Implementation of sustainable mobility measures can reduce energy needs, GHG emissions, improve air quality, reduce noise pollution, and lead to a reduction of road danger.
EXTERNAL LINKS	• Guidelines for developing and implementing a Sustainable Urban Mobility Plan (Eltis, The Urban Mobility Observatory) • Sustainable Urban Mobility Plans (SUMPs) - Mobilise Your City • Mobility and transports Local Practices (CEREMA)

3.8.22 Decarbonisation Plans for Industry

- Authors: **Tecnalia**
- Knowledge Repository link: **https://netzerocities.app/resource-1718**

Decarbonisation Plans for Industry
Many **companies** have publicly declared their intention to become **carbon neutral** in following years. Some due to CO2 emissions price (which is experiencing high increases and implies higher costs for industries), some due to marketing strategies and some because they believe that they also need to contribute to the transition. The EU Emissions Trading System (ETS) already covers sectors not included under the ESR and makes polluters to decarbonize. Also, mechanisms such as the Carbon Border Adjustment Mechanism (CBAM) will also play and important role. Development of **decarbonization plans for companies** is the main instrument for elaborating not only a current diagnosis of the situation but also to understand potential evolution (prospective), analyse solutions and prepare the company to take decisions without losing competitiveness.

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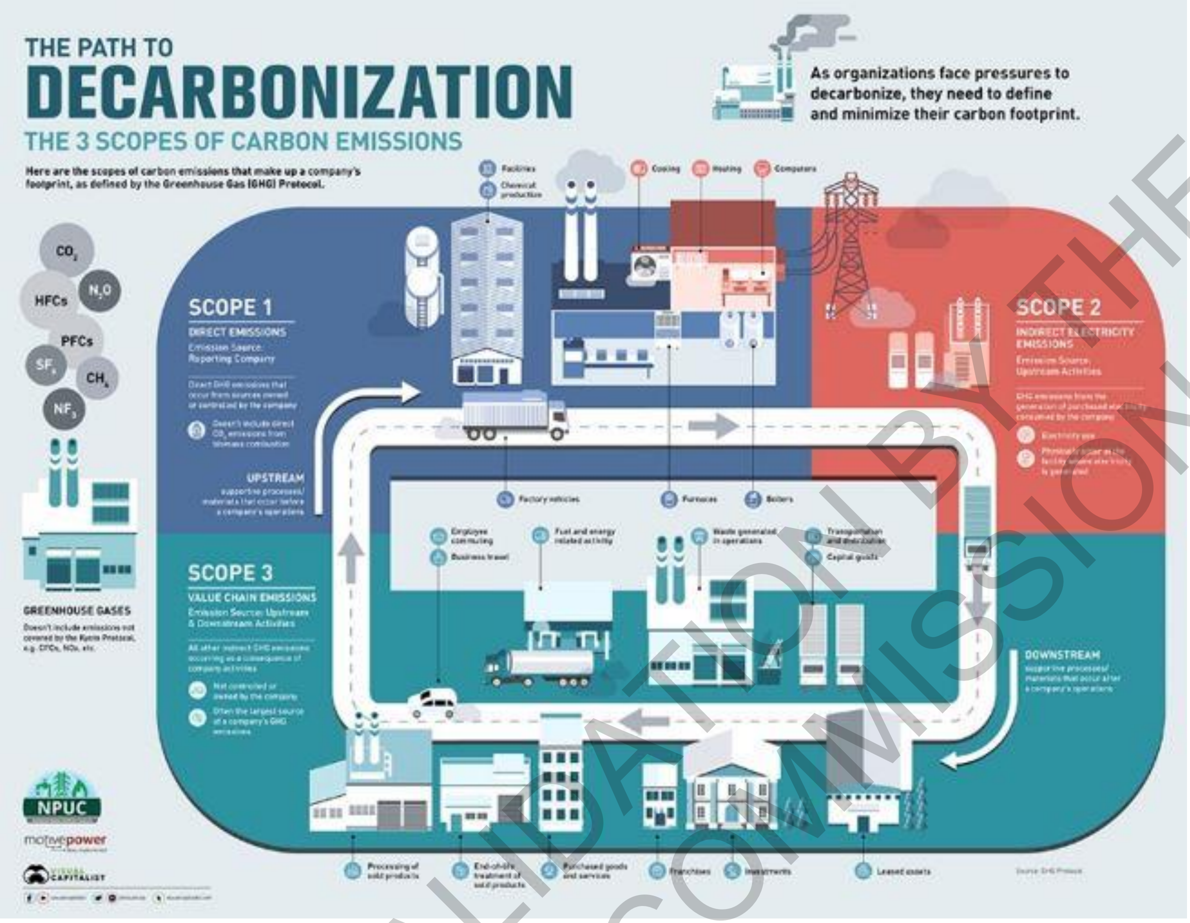
Decarbonisation Plans for Industry



Decarbonization 101: What Carbon Emissions Are Part Of Your Footprint? Source: visualcapitalist.com

1. The first step is to **measure and analyse current situation**. There are different methodologies for the evaluation of emissions at companies (GHG protocol is the most used one). But there is a gap in consistent and credible measurement. Specially, when it comes to evaluate Scope 3.
2. Second step is to **model future needs, energy demands**, etc. according to **market evolution, production changes, expected investments**, etc. All that will be very valuable to picture the future situation and start defining what needs to be done to decarbonize.
3. Last step will be to **analyse all solutions** that can help decarbonizing the company without compromising its economy and development. Main working areas will be: Energy efficiency (to reduce consumption), auto generation (to increase autonomy through renewables), green supply (for electricity, heating & cooling, transportation, etc.) and carbon capture, storage and reuse. Circularity is also an important aspect to work with (reuse and recyclability).

CO-BENEFITS	Decarbonization in companies will have a direct co-benefit in the **reduction of GHG emissions** and therefore the **air quality** would be improved. But it will also offer opportunities for the development of new technology solutions and improve overall **quality of life**. Co-benefits in the areas of adaptation providing higher resiliency to companies, in decreasing future maintenance costs and obviously in all climate mitigation co-benefits.
EXTERNAL LINKS	• EU Emissions Trading System (EU ETS) • Industrial decarbonisation strategy - Policy paper (gov.uk)

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This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

3.8.23 City water resilience assessment

- Authors: **Resilient Cities Network**
- Knowledge Repository link: **https://netzerocities.app/resource-1738**

City water resilience assessment

Water is a fundamental and unique resource necessary for survival in nature and the development of human settlements. Within cities, water provides a series of tangible and intangible services to citizens, including drinking, sanitation, hygiene and amenity. Water interacts with other urban systems and infrastructure (e.g. flooding of roads, buildings) and includes a variety of possible uses (drinking and wastewater, blue-green infrastructure). In this perspective, water can improve or impair livelihoods.

The **City Water Resilience Assessment (CWRA)** provides a useful guide for cities to understand water from a systemic perspective (including water sources, treatment options, pipelines networks and management practices, types of uses, but also resilience to a changing climate). As a result, the CWRA can support stakeholders identify measures for **Sustainable Water Management** through relevant urban policies and interventions (e.g. Water Sensitive Urban Design). For instance, storm water could become an additional resource through its integration in NBS, rather than a problem to be quickly eliminated from the (drained) city.

The City Water Resilience Framework presented in the City Water Resilience Approach

While typically the main driver for applying the CWRA is **adaptation to climate change** (primarily managing floods and droughts), it inevitably examines/promotes circularity of water resource flows. Within this context, the way we manage urban water has direct implications on its embedded life-cycle carbon, e.g. carbon from source to tap to wastewater, considering also emissions in the construction and maintenance of grey infrastructure. With an increasing attention on urban carbon neutrality, CWRA can contribute to rethinking low-carbon contributions from our water systems.

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City water resilience assessment	
The City Water Resilience Assessment inevitably needs to be contextualized, identifying the scale and the elements which are part of the water systems (i.e. urban rivers, canals, ponds, swales, ground water, and pipelines). The CWRA should be seen as process of analysis and not as a tool for generating results. Yet, modelling tools are necessary to produce quantitative results that can provide the evidence base required for informed decisions/assessments as part of CWRA. To this end, the successful application of the CWRA requires the successful engagement of local experts, stakeholders and communities.	
CO-BENEFITS	The City Water Resilience Framework can contribute to climate resilience and climate adaptation, in particular reducing the risk to natural and climate hazards and enhancing the stability of the urban infrastructure. Other co-benefits clearly include **water efficiency**, such as improved water quality and improved the consultation with stakeholders and communities, **enhancing citizen participation**, connectivity and community. Last but not least, a better design, functioning and distribution of the water system can support local **biodiversity** and increase the **attractiveness of the city**.
KEYWORDS	The City Water Resilience Framework can be strongly related to all the technical solutions related to water, such as hard-drainage flood prevention, water retention pounds, constructed wetlands and rain gardens. More broadly, it can be linked to Green Infrastructure and NBS plans and strategy.
EXTERNAL LINKS	Sources: • https://www.arup.com/perspectives/publications/research/section/the-city-water-resilience-approach • https://siwi.org/city-water-resilience-approach/?accordion-our-approach • https://www.resilienceshift.org/campaign/city-water-resilience-approach/ • https://www.resilienceshift.org/wp-content/uploads/2020/01/Cape_Town_WaterResilienceProfile_FINAL.pdf • https://resilientcitiesnetwork.org/downloadable_resources/Programs/091
EXAMPLES	A relevant example is the City Water Resilience Framework Approach (CWRA), developed by **Arup**, the **Resilience Shift**, the **Stockholm International Water Institute (SIWI)**, and the **Rockefeller Foundation**. The goal of the CWRA is to guide cities in building water resilience at the urban scale, growing cities' capacity to provide high quality water resources, protect from water-related hazards, and connect through water-based transportation networks. Some of the member cities of Resilient Cities Network (for instance Cape Town and Addis Ababa) have carried out a Water Resilience Assessment to identify water-related shocks and stresses and develop strategies for addressing those.

3.8.24 Governance EU Climate Neutrality Framework

- Authors: **Energy Cities**
- Knowledge Repository link: **https://netzerocities.app/resource-1728**

Governance EU Climate Neutrality Framework
Key EU legislations aim at **transforming and decarbonising** the European **building stock.** This includes: • The Clean Energy Package for all Europeans – a comprehensive set of legislation that defines European climate and energy policy beyond 2020. • The Energy Performance of Buildings Directive (EPBD), • The Energy Efficiency Directive (EED), and • The Renewable Energy Directive (RED) cover the main issues regarding building policies on a European level.

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Governance EU Climate Neutrality Framework

- A new Circular Economy Action Plan (CEAP) was adopted in March 2020. It includes measures that will help stimulate Europe's transition towards a circular economy and encompasses the entire life cycle of products and key value chains, including construction and buildings.
- The National Energy and Climate Plans (NECPs) are closely interlinked with
- National Long-term renovation strategies (LTRS) and outline how Member States plan to reach their climate and energy targets.

Source: Jan Jakub Nanista on Unsplash

In addition to legislation, the EU has also adopted a series of initiatives to support Member States, increase knowledge about EU building stock, and monitor its progress over time: the Building Stock Observatory (BSO) collects data on all building typologies across the EU; while national databases on Energy Performance Certificates (EPC) are meant to provide up-to-date information on the performance of buildings sold, rented or which have undergone major renovations. LTRS and NECP also provide data on national building stock. This can help to assess the achievement of goals, compare different countries and building types, and monitor the effectiveness of policies and financial instruments.

CO-BENEFITS	Some of the co-benefits are: • Reduce GHG emissions • Reduce energy needs • Increase employment rate and Jobs • Enhance attractiveness of the cities • Better access to living areas for all
EXTERNAL LINKS	• EU Clean energy package for all Europeans • EU Directive on the Energy Performance of Buildings (EPBD) • EU Energy Efficiency Directive (EED) • EU Renewable Energy Directive (RED) • EU Circular Economy Action Plan (CEAP) • National Energy and Climate Action Plans (NECPs) • National Long-Term Renovation Strategies (LTRSs) • EU Building Stock Observatory (BSO) • A guidebook to European building policy: Key legislation and initiatives (BPIE, 2020)

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3.8.25 Data strategy

- Authors: **AIT**
- Knowledge Repository link: **https://netzerocities.app/resource-2149**

Data strategy	
A data strategy is a long-term plan that defines the technology, processes, people, and rules required to manage an organization's information assets. All types of businesses collect large amounts of raw data today. However, they need a well-thought-out data management and analysis plan if they want to use this information to make informed decisions. A data strategy outlines an organization's long-term vision for collecting, storing, sharing, and usage of its data.	
CO-BENEFITS	A data strategy contains steps on various levels to reach a defined goal. In doing so, the goal could be to Reduce risk to natural and climate hazards, Enhance stability of the urban infrastructure, Reduce energy needs, Reduce hot spots/urban heat islands in the city, Enhance attractiveness of the cities, and hence, support Healthier and more attractive lifestyles.
EXTERNAL LINKS	• https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-data-strategy_en

3.8.26 Public procurement for innovative NBS and Green Infrastructure interventions

- Authors: **METABOLIC, Resilient Cities Network**
- Knowledge Repository link: **https://netzerocities.app/resource-588**

Public procurement for innovative NBS and Green Infrastructure interventions	
The public contract is a type of contract in which at least one of the parties is a public Administration, and there is a situation of legal subordination. Public procurement offers potential market for innovative Nature-Based Solutions (NBS) and Green Infrastructure (GI). The public procurement of NBS refers to the procurement of solutions, and verifiable environmental and social criteria can be included when "purchasing" NBS.	
CO-BENEFITS	Public procurement of NBS stimulates innovation by promoting the competitiveness among bidders, who increase the quality of the offer including more value into their proposals. Some benefits are: • Impulse co-creation on NBS implementation process, by including it as a requisite. • Foster competition. • Using a single point of contact for project management. • Support the development of key NBS performance indicators. • Promote cross-departmental exchange • Increase NBS network. • Use pilot projects to build trust in the community. • Encourage suppliers to think creatively about community engagement.
EXTERNAL LINKS	Source/Additional information: European Commission, Directorate-General for Research and Innovation, Mačiulytė, E., Durieux, E., Public procurement of nature-based solutions: addressing barriers to the procurement of urban NBS: case studies and recommendations, Publications Office (2020) Available at: https://data.europa.eu/doi/10.2777/561021 The case studies were collected from European cities, that have procured or are planning to procure NBS (or in some cases NBS planning services). With the

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Public procurement for innovative NBS and Green Infrastructure interventions	
	exception of one city (Frederiksberg), those NBS projects were supported by the Horizon 2020 funding programme. Information was kindly provided by the municipal representatives of the cities of Manchester, Wroclaw, Glasgow, Turin, Eindhoven, Genoa, Tampere, London, and Frederiksberg, as well as project officers of UNaLab, Clever Cities, ProGiReg, GrowGreen, and Connecting Nature. This information-gathering exercise took place between April 2019 and September 2020.
PRE-CONDITIONS & ENABLING CONDITIONS	***Political*** Mature land use management and urban planning, encourage suppliers to think creatively about community engagement ***Economic*** Inversion in research. ***Social*** Commitment, environment education, join an NBS network, pilot projects to build trust in the community. ***Technical*** Centres of excellence on NbS procurement, provide policy support to NBS projects, promotion cross-departmental exchange, wide range of technical solutions available for NBS. ***Legal*** Legal umbrella to stablish green infrastructure and NbS ordinances and regulation, grouping NbS contracts together.
CONSTRAINTS/ BARRIERS for implementation	***Political*** Lack of commitment, difficult to put together a convincing business case for projects. ***Economic*** NbS projects might not be prioritised in strict budgets. ***Social*** Negative experiences of engaging with public authorities, lack of trust in city's commitment to delivering NBS projects ***Technical*** The lack of knowledge and experience with NBS among procurement practitioners' problems using public procurement to implement NbS projects, widespread confusion between the terms, difficulty to compile universal NBS cost guidelines, lack of the information and/or skills and capacity to apply effective tools and methods to assess the diverse benefits, technical requirements are high, public authorities report difficulties in finding suppliers willing to bid for NBS projects. ***Legal*** Lack the political and institutional support to drive forward NBS projects.
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	**Manchester** engaged with its neighbouring municipality - Salford City Council - to discuss their difficulty in identifying suitable suppliers. Through those discussions, it appeared that Salford City Council had access to a good pool of landscaping contractors through one of its existing procurement frameworks. It has faced flooding problems with NbS (sponge park). **Wroclaw** has enhanced NbS to reduce flooding and heat stress. The condition related to expertise in sustainable rainwater management and design had to be lifted, as it turned out to be impossible to achieve. The formal/financial requirements were lowered to raise the interest of landscaping SMEs. The second call for tender has been successful, however, only one proposal was submitted per demonstrator site.

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Public procurement for innovative NBS and Green Infrastructure interventions	
	Glasgow has developed alternative delivery routes to avoid the need to go through its own procurement procedures NBS projects. The parks development and flooding teams regularly collaborate with charities and other public bodies whose procurement powers are less restricted. Promotion of more efficient and effective cooperation between the planning department. **Genoa** provided a valuable opportunity for the different municipal agencies and departments to collaborate. Additionally, it has inspired the city administration to include NbS among the requirements for the design of another urban park for the city of Genoa.
IMPACTS (Indicators & DNSH)	The DNSH principle is considered as the public procurement considering NBS allows the: • The protection and restoration of biodiversity and ecosystems • Climate change adaptation

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3.8.27 Building Renovation Passport (BRP)

- Authors: **CARTIF**
- Knowledge Repository link: https://netzerocities.app/resource-1748

Building Renovation Passport (BRP)
A **Building Renovation Passport (BRP)** is a document (either electronic or in paper format) outlining a long-term (up to 15-20 years) **step-by-step renovation roadmap** to achieve deep renovation for a specific building. It addresses the complexity of renovation works and ensures coordination throughout the different stages. They are conceived as an **evolution of the Energy Performance Certificate** (EPC), as it supports building owners with personalised suggestions on their renovation options, while accelerating deep renovation. The BRP can also link to a **logbook**, a (digital) repository where the building's information can be stored and updated.

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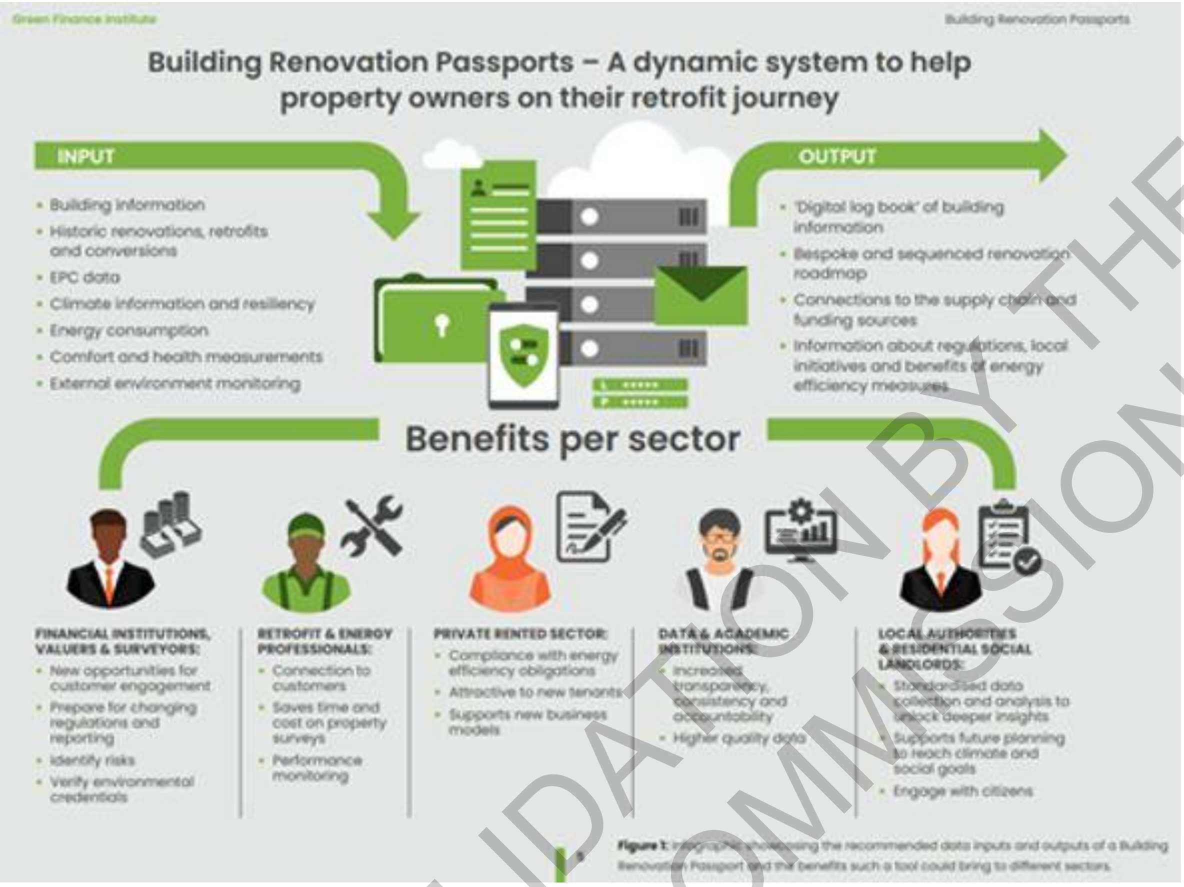
Building Renovation Passport (BRP)



Building Renovation Passports as a dynamic system to help property owners on their retrofit journey. Source: Green Finance Institute

The suggested options result from an **on-site energy audit** fulfilling specific quality criteria and indicators established in dialogue with the owner. The BRP presents renovation as a home-improvement plan, not just as a technical intervention. It is based on the occupant's needs and specific situations (e.g. age, financial situation, composition of the household, etc.) and outlines each step and links proposed measures, and the related **expected benefits**, **including energy savings and comfort improvement**. By doing so, owners can fully understand and embrace the project.

A benefit of the Building Renovation Passports are related to the uptake and **accomplishment of the EPBD** (Energy Performance Buildings Directive), since by encouraging deep renovation, it results in **deep renovation of the building stock**; it is part of the list of instruments that can be used to link financial measures with the energy savings achieved through renovation; and it is an effective and transparent advisory tool available to all consumers, it can **empower citizens** to make the right renovation choices.

CO-BENEFITS	Expected benefits are related to **reduce the energy needs** of the building thanks to a better insulation and energy performance, thus leads also to a **reduction of GHG emissions**, while **decreasing future maintenance costs** due to recent renovation and better materials and systems. The renovated buildings will also enhance the **attractiveness of the cities**, as well as the **comfort improvement** for its inhabitants. As instrument to be adopted, it will also **build social capacity**.
KEYWORDS	It is directly linked with the Energy Performance Certificates (EPC), Key Regulation at EU level, and Digital Building Logbook. As well as to other solutions related to retrofitting/refurbishment of buildings.
EXTERNAL LINKS	• European Commission, Final report - Technical study on the possible introduction of optional building renovation passports • BPIE, Building Renovation Passports - Customised roadmaps towards deep renovation and better homes

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Building Renovation Passport (BRP)	
	• Fabbri, M. (BPIE), 2017. Understanding building renovation passports: customised solutions to boost deep renovation and increase comfort in a decarbonised Europe. ECEEE Summer Study Proceedings (6-227) • Green Finance Institute. Building Renovation Passports: Creating the pathway to zero carbon homes • Introducing Building Renovation Passports in Ireland, Feasibility Study (IGBC)

3.8.28 Smart Readiness Indicator (SRI)

- Authors: **CEREMA**
- Knowledge Repository link: **https://netzerocities.app/resource-1758**

Smart Readiness Indicator (SRI)

The potential of smart technologies in the building sector was emphasised in the 2018 revision of the European Energy Performance of Buildings Directive (**EPBD**) and the **Smart Readiness Indicator (SRI)** was introduced, followed by two legal acts in 2020 which establish the SRI as an official EU instrument. The European directive doesn't impose the deployment of the SRI on each Member State, it's for the moment optional, but Europe plans to further strengthen the SRI to ensure its generalization in large new buildings.

The SRI is a common EU scheme for **rating the smart readiness of buildings**. The SRI assesses how smart a building is in terms of:

- responding to the **needs of the occupant** (e.g. health, comfort, well-being, etc.);
- using **energy efficient control strategies**;
- **interacting with energy grids** (energy flexibility / demand response and system integration).

Why is it relevant:

- Using **smart technologies in buildings** can be a cost-effective way to assist in creating healthier and more comfortable buildings with lower energy use and carbon emissions. For instance:
  - Digital technologies such as smart thermostats and lighting control can pay back within 2 years.

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Smart Readiness Indicator (SRI)	
• Smart technologies, such as automated sun shading control or ventilation control based on air-quality sensors, can also improve health, well-being and comfort. • Intelligent scheduling of energy consumption (white goods, electric vehicles, etc.) can result in significant energy savings, and at the same time it contributes to grid balancing. • The SRI provides a **common language for building stakeholders** (owners, designers, solution providers, policy actors, etc.) to discuss how to make buildings smarter, and what benefits this will bring.	
CO-BENEFITS	Main co-benefits of the SRI are: • **Climate mitigation**: Reduction of energy consumption (needs) and GHG emissions, and reduction. At building scale, an average 30% savings of final energy can be obtained when implementing an advanced package of smart building technologies. Some of the single optimisation measures are easy to implement with a short payback period (e.g. exchange of thermostatic valves, boiler and pump adjustments, night setbacks, etc.). • **Entrepreneurship and innovation**: Increase technological readiness and decrease future maintenance costs.
KEYWORDS	Some of the solutions with a direct link to SRI are: smart technology, Smart Readiness Indicator, smart grid, digital, European Energy Performance of Buildings Directive, EPBD.
EXTERNAL LINKS	• SRI website, FAQ and resources • Application of smart readiness indicator (SRI) for Mediterranean buildings in retrofitting actions

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3.8.29 Mobility Management

- Authors: **Rupprecht**
- Knowledge Repository link: **https://netzerocities.app/resource-1768**

Mobility Management

Even the best sustainable mobility solutions will only be effective if they are used. **Mobility Management** refers to the **promotion of sustainable transport** and managing the demand for car use by offering services with the final objective of changing travellers' attitudes and mobility behaviour. At the core of mobility management are **"soft" measures** such as information and marketing campaigns, awareness raising, mobility education, mobility info points, and school and company travel plans. "Soft" measures most often enhance the effectiveness of **"hard" measures** within urban transport (e.g. new tram lines, new bike lanes or charging infrastructure). Compared to "hard" measures, mobility management measures do not necessarily require large financial investments and may have a high cost-benefit ratio in a short time frame.

Source: EPOMM

Mobility Management	
In a city where mobility management is implemented, one could, for example, move around using widely **available shared transport systems** (such as cars, (e-)bikes and e-scooters) and consult the local mobility centre to plan a leisure trip using public transport. In addition, employers could provide incentives for their employees to use public transport to and from the office to discourage them from commuting by car. For mobility management measures to be effective, it is important to **engage stakeholders** early on to gain buy-in for the measures to be implemented. Also, they should be limited in their geographic scope, be context specific and demand driven. Ideally, mobility management measures are part of a **Sustainable Urban Mobility Plan (SUMP)**. This ensures that mobility management measures are implemented in an **integrated way** with other mobility measures, leading to the desired overall goals of increasing the use of sustainable transport modes, reducing greenhouse gas emissions, and improving air quality. In the end, mobility management measures not only have an impact on the ways in which people move around, but also more broadly on the liveability of urban spaces.	
CO-BENEFITS	**Reduce GHG emissions**, reduce energy needs, **sharing economy**, enhancing citizen participation, raised awareness/behavioural change, **improve air quality, reduce noise pollution**, **healthier and more attractive lifestyles**, better physical activity of individuals.
EXTERNAL LINKS	• EPOMM - The European Platform on Mobility Management: https://epomm.eu • Eltis: The Urban Mobility Observatory - Mobility Management insights and examples to successful implementation • Behavioural change & mobility management (CIVITAS) • Mobility Management (CIVITAS learning centre)

3.8.30 Urban Vehicle Access Regulations (UVAR)

- Authors: **Rupprecht**
- Knowledge Repository link: **https://netzerocities.app/resource-1778**

Urban Vehicle Access Regulations (UVAR)

Urban vehicle access regulations (UVARs) are means to reduce the number of vehicles entering a given geographical area. These can include **regulatory measures** (e.g. low-emission zone), **financial measures** (e.g. congestion charge) or **spatial measures** (e.g. creation of a superblock or reallocation of road space to create a pedestrian zone).

UVAR measures can be put in place for **reasons** such as: to create more liveable space, to encourage more walking or cycling, to address delivery issues such as congestion or kerb space access, to reduce air pollutant emissions (e.g. PM, NOx) or greenhouse gas emissions (e.g. CO2), to reduce speed and/or noise, to reduce motorised traffic levels, through traffic, congestion and/or injuries.

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Urban Vehicle Access Regulations (UVAR)	
These **"stick" measures** (as opposed to "carrot" measures) put restrictions on vehicle access to given areas, while **maintaining access for people and for goods**. As such, it is important to work closely with citizens and stakeholders to ensure they understand the purpose of the restrictions and that no equity issues arise.	
CO-BENEFITS	**Reduce GHG emissions**, reduce energy needs, **boost local business**, proximity economy, sharing economy, raised awareness/**behavioural change**, improve **land use management**, **improve air quality**, **reduce noise pollution**, reduce hot spots/urban heat islands, reduction of road danger, **enhance attractiveness of cities**, healthier and more attractive lifestyles, better access to living areas for all.
KEYWORDS	This solution is directly connected to others such as SUMPs, Land use planning and urban space management, Low emission zones, electric cars, electric buses, Road/congestion pricing.
EXTERNAL LINKS	• Topic Guide: UVAR and SUMPs - Regulating vehicle access to cities as part of integrated mobility policies (ELTIS, European Platform on sustainable Urban Mobility Plans) • CIVITAS ReVeAL project: it will help to add Urban Vehicle Access Regulations to the standard range of urban mobility transition approaches of cities across Europe • Urban Access Regulations in Europe MAP • UVAR Box & UVAR Exchange: Digitising & exchanging data of urban vehicle access regulations (UVAR) across Europe to facilitate the private, public and commercial use of UVARs

3.8.31 Low-Emission Zones

- Authors: **Rupprecht**
- Knowledge Repository link: **https://netzerocities.app/resource-1788**

Low-Emission Zones
A **low-emission zone** (LEZ) is an example of an urban vehicle access regulation (UVAR). A LEZ is a geographic area in a city where vehicle access is limited to those vehicles that meet certain emissions characteristics. A LEZ is a regulatory measure that enables a city to reduce the level of emissions in a given geographic area. Low-emission zones are generally **introduced in stages**, meaning they become increasingly strict over the course of several years. This **allows citizens and businesses time to adapt** to the changes by purchasing lower-emitting vehicles, retrofitting existing vehicles where possible or finding other modes of transport within the LEZ area (e.g., walking, cycling, public transport, e-scooters). **Early and regular communication** allows citizens to adapt their behaviour to the new situation.

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Low-Emission Zones	
Stricter versions of a low-emission zone can include **ultra-low-emission zones** or **zero-emission zones**. Enforcement must be carefully considered so that only vehicles meeting the current standards are able to access the zone. This may be challenging when dealing with foreign-registered vehicles. It should be noted, LEZs only act on emission standards, independent of the number of kilometres driven, i.e. they do not help to reduce the total number of vehicles in an area.	
CO-BENEFITS	Reduction of GHG emissions, reduction of energy needs, improved land use management, improved air quality, reduction of hot spots/urban heat islands.
KEYWORDS	Solutions with direct connections: SUMPs, Land use planning and urban space management, Urban vehicle access restrictions, low-emission cars, low-emission buses.
EXTERNAL LINKS	• Topic Guide: UVAR and SUMPs - Regulating vehicle access to cities as part of integrated mobility policies (ELTIS, European Platform on sustainable Urban Mobility Plans) • CIVITAS ReVeAL project: it will help to add Urban Vehicle Access Regulations to the standard range of urban mobility transition approaches of cities across Europe • Urban Access Regulations in Europe MAP • UVAR Box & UVAR Exchange: Digitising & exchanging data of urban vehicle access regulations (UVAR) across Europe to facilitate the private, public and commercial use of UVARs

3.8.32 NBS and Green Infrastructure regulation and ordinances

- Authors: **Tecnalia**
- Knowledge Repository link: **https://netzerocities.app/resource-1813**

NBS and Green Infrastructure regulation and ordinances	
Ordinances and regulation are the legal mechanisms of local governments for land use and natural resource management. In many cases, both **Nature-Based Solutions (NBS) and Green Infrastructures (GI)** can be part of **prevention and development instruments**. They can preserve natural areas, reduce impervious surface cover and manage climate risks. **Ordinances** improve the connectivity of NBS and GI, enhance the surface they represent, avoid their deterioration. Local ordinances can **protect** wetlands, natural spaces, aquifers, among others. Ordinances are not only key elements to design NBS and GI, but also important instruments to **maintain** them. Besides, local government can **map and identify natural resources** to protect them under a legal umbrella. The **regulation** of NBS and GI provides clusters and controls urban growth preserving natural areas. Thus, some activities can be prohibited in order to correctly maintain those spaces. Local governments tend to tackle urban challenges building grey infrastructure, however, NBS and GI ordinances and regulations can provide more **resilient solutions**. Moreover, ordinances can provide new urban development towards areas that will have less impact on natural resources.	
EXTERNAL LINKS	• Tackling Barriers to Green Infrastructure: An Audit of Municipal Codes and Ordinances (U.S. Climate Resilience Toolkit)
EXAMPLES	• Regulatory Strategies to Incorporate Green Infrastructure for North Carolina (NC Forest Service) • Governing metropolitan green infrastructure in the United States (Landscape and Urban Planning, 2013) • Opportunities for green infrastructure under Ecuador's new legal framework (Landscape and Urban Planning, 2017)
PRE-CONDITIONS &	***Political*** Mature land use management and urban planning.

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NBS and Green Infrastructure regulation and ordinances	
ENABLING CONDITIONS	***Economic*** Inversion in research and maintenance on green areas. ***Social*** Commitment, environment education. ***Technical*** Enough technicians and lawyer, green areas mapping and identification. ***Legal*** Legal umbrella to stablish green infrastructure and NBS ordinances and regulation.
CONSTRAINTS/ BARRIERS for implementation	***Political*** Lack of commitment. ***Economic*** Reduce new building construction, economic interests instead of environment protection. ***Social*** No participation to enhance the solution, no acceptation of society, no environment awareness, no environment education. ***Technical*** Lack of technicians, environment related laws, lack of land management legislation instruments, long-term planning. ***Legal*** No planning instruments that support.
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	In the cases of New York, Denver, Houston, L.A. and Sacramento had a positive effect on existing regulations or positively influenced those under development. However, in Salt Lake City it had negative effect. In Ecuador green infrastructure is an opportunity to designate protected tourist areas. Recent national legislation in Ecuador is highly favourable to green infrastructure, but implementation will depend on land-use and water management decisions at the local level. In Wroclaw the new ordinance about green infrastructure in 2019 improves green areas in terms of planning.

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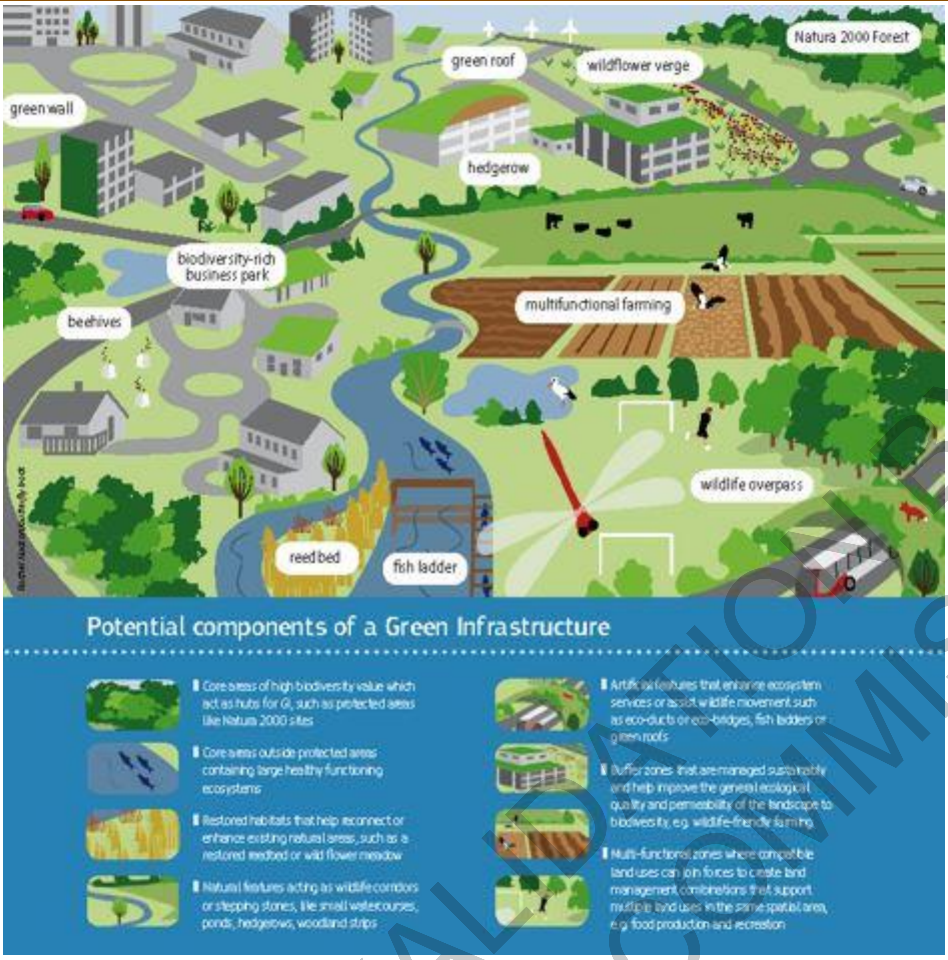
3.8.33 NBS and Green Infrastructure plans and strategy deisgn and governance

- Authors: **Resilient Cities Network**
- Knowledge Repository link: https://netzerocities.app/resource-1823

NBS and Green Infrastructure plans and strategy design and governance
Thanks to their multifunctionality, NBS can address several urban challenges, in particular related to climate change, urban resilience and human health and well-being. For this reason, NBS require **proactive policy intervention** to be mainstreamed and integrated into urban policies, planning processes, and decision-making mechanisms.

This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

NBS and Green Infrastructure plans and strategy design and governance



Source: EEA (European Environment Agency)

Designing NBS and Green Infrastructure plans and strategies can support other **policy documents** and have an impact in terms of **spatial development**, **environmental protection**, noise level reduction, **low carbon economy plans**.

In terms of **governance**, the nature of NBS require large **collaboration partnerships and participation**. For instance, several cities are experimenting **co-creation and co-design processes** established in Living Labs, together with local communities and stakeholders. Nevertheless, the success of NBS as a concept in supporting urban transformation will largely depend on the extent to which **NBS are embedded in urban planning** and development processes. In fact, there is significant potential to use NBS as a “tool” to achieve objectives set in existing or future strategies (e.g. sustainable urban mobility plans, resilience strategies, land use plans, housing licencing policies).

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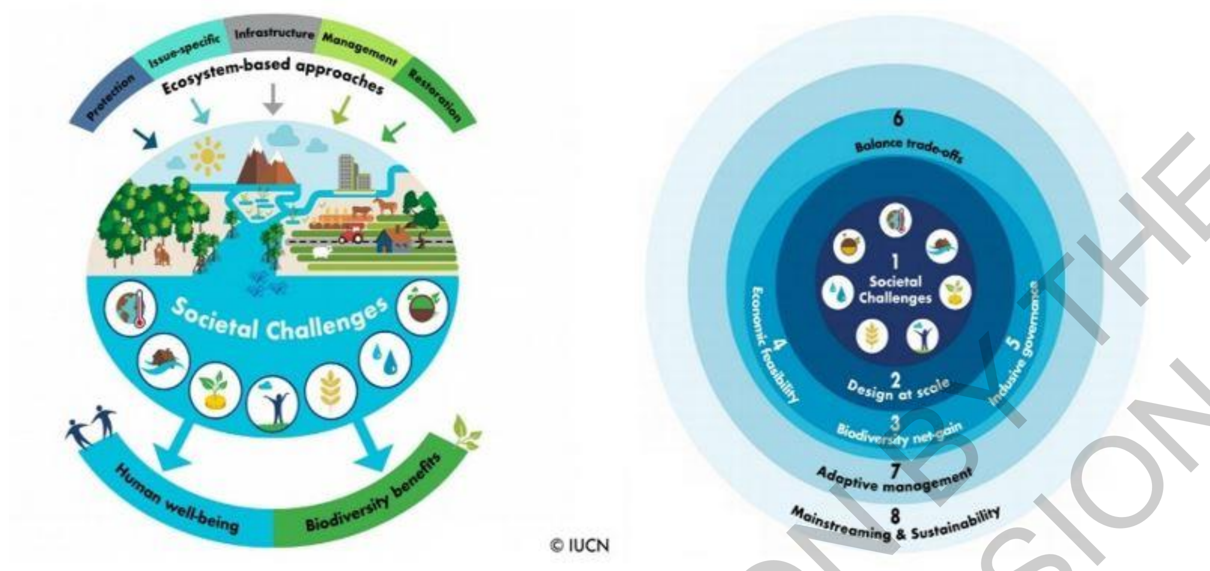
NBS and Green Infrastructure plans and strategy design and governance	
 *Source: IUCN (International Union for Conservation of Nature)*	
CO-BENEFITS	NBS and Green Infrastructure contribute to many co-benefits. Good governance and management processes facilitate the technical implementation of plans and strategies, increasing the potential benefits. In general, NBS and Green Infrastructure plans and strategy contribute to the following co-benefits: improve **land-use management**; improve **air quality**; **reduce heat island effect**; enhance attractiveness of the cities; better access to living areas for all; increase ecological connectivity.
KEYWORDS	In terms of other solutions, it potentially links with all the other technical interventions (**renaturing urbanization**, **single green infrastructure** and **water interventions**). Regarding non-technical solutions, it links to **engagement**, **co-creation** and **co-design** of NBS and Green Infrastructure plans and interventions, as well as NBS and Green Infrastructure **regulation and ordinances**.
EXTERNAL LINKS	• Evaluating the impact of Nature-based Solutions: a handbook for practitioners (EU-funded Horizon 2020 NBS projects, EEA and JRC as part of the European Taskforce for NBS Impact Assessment) • The EU Strategy on Green Infrastructure • Municipal Governance for Nature-based Solutions: Executive Summary of the UnaLab Municipal Governance Guidelines August 2019 (UnaLab, Fraunhofer IAO) • ThinkNature Nature-Based Solutions Handbook (OPPLA EU, ThinkNature project) • Nature-based Solutions (Geneva Environment Work) • What is green infrastructure? (EEA: European Environment Agency)

3.8.34 Building Material Passport (BIM-based)

- Authors: **CARTIF**
- Knowledge Repository link: **https://netzerocities.app/resource-1833**

Building Material Passport (BIM-based)
The **Building Material Passport (BMP)** is a document (either electronic or in paper format) that contains the information on products, components and materials existing in a building, as well as their quantities. These data are obtained from the information included in the **BIM (Building Information**

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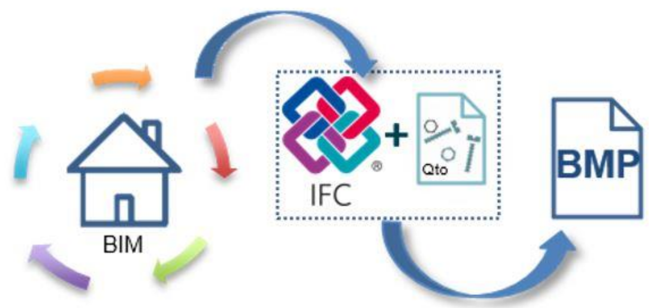
Building Material Passport (BIM-based)

Modelling) model of the building, based on the **IFC** (Industry Foundation Classes) standard. Depending of the Level of Development of the BIM model, additional external information on materials and quantities of each component will be required and provided by a technical user (e.g. the quantity of existing screws), to have a Material Passport of the building that is as accurate as possible.



Source: © Sonia Álvarez Díaz, CARTIF

This BMP has the **material inventory function**, which allow building owners/ architects/public entities to know all products, components and materials, and their quantities, available in a building, allowing also to update them in the future and to **perform a financial valuation**. The information containing in the BMP can be used as input of different local materials bank solutions.

This will be important in the **reuse and recycling stage of a product life cycle** of the products, components and materials included in a building.

This solution can be applied in **both new and existing buildings** and can be used as input to calculate the **LCA** (Life Cycle Assessment), both in the definition of the materials to be used in the design phase, and in the renovation phase of a building. For the **demolition phase**, this BMP is of great interest as it shows the amount of materials that are available for recycling or reuse.

CO-BENEFITS	Some of the co-benefits of the Building Material Passport are to **boost local business** (km 0), **sharing economy** or **promote the materials cycle**. The BMP will encourage the **recycling of materials** and promote the local economy by connecting with local materials banks.
KEYWORDS	BMP has direct connection with solutions such as Digital Building Logbook, re-using local building waste, online register with building and infrastructure for reuse/circular use, and Circular Life Cycle Cost (C-LCC) for deep renovation. It has also connection with other solutions such as Circular Life Cycle Assessment/ Analysis for material and products; and with other solutions related to retrofitting/refurbishment of buildings.
EXTERNAL LINKS	• The Building Passport Practical Guidelines (UN environment programme, Global Alliance for Buildings and Construction) • Material Passport of the HOUSEFUL project • Madaster platform

3.8.35 Turnkey Retrofit Service

- Authors: **Tecnalia**
- Knowledge Repository link: **https://netzerocities.app/resource-1843**

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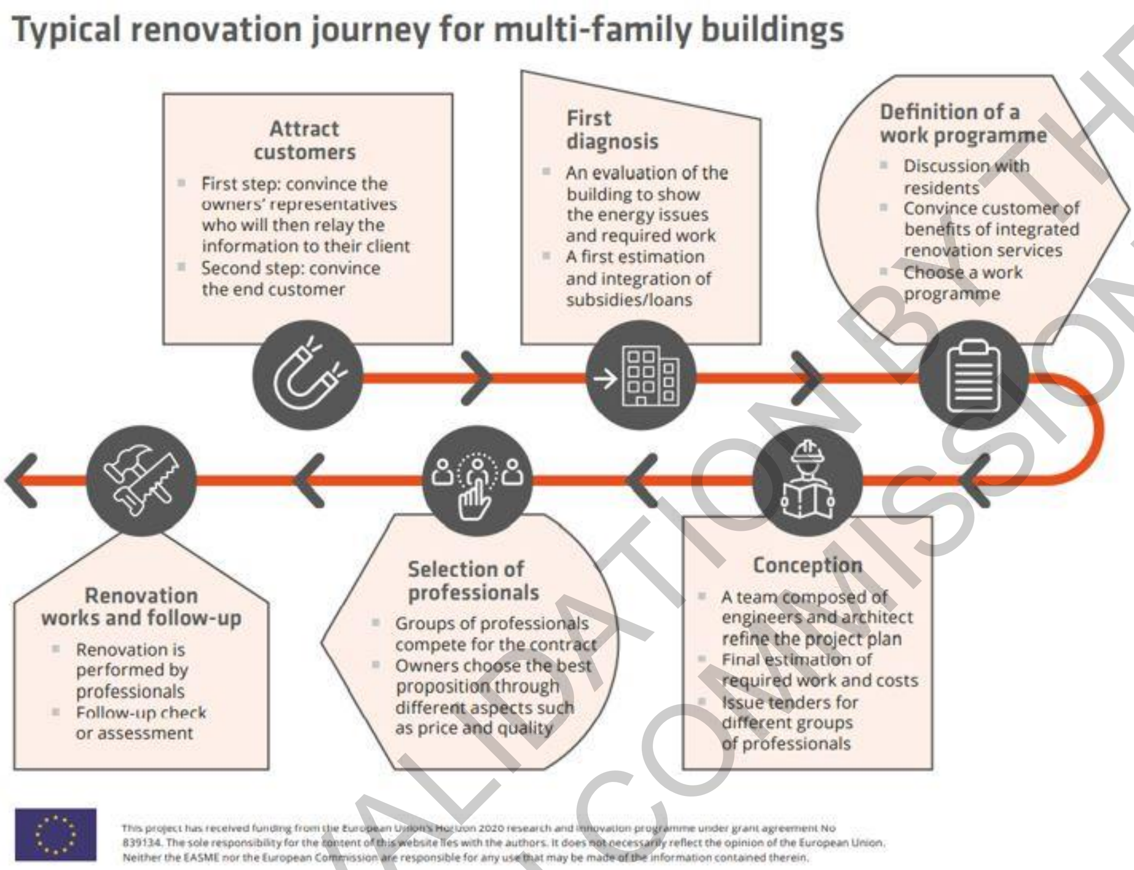
Turnkey Retrofit Service

The **Turnkey Retrofit service** is developed as a **homeowner-centric renovation journey**, transforming the complex and fragmented renovation process into a simple, straightforward and attractive process: all providers on one platform, where trust is key.



Source: Turnkey Retrofit EU

Integrated home renovation service supporting homeowners with a turnkey solution for:

- **INFORMATION ABOUT THEIR HOME** (INITIAL TECHNICAL AND SOCIAL/ BEHAVIOURAL DIAGNOSIS): digital solution providing an overview of alternatives and a first cost estimation based on publicly-available energy data for a specific address, the service will consider behavioural aspects to raise awareness and nudge the occupants to use their energy more wisely;
- **POTENTIAL WORKS** (TECHNICAL AND ECONOMICAL OFFERS): jointly elaborated by selected local market actors of the Turnkey Retrofit community, which will adhere to the overall integrated methodology and be committed to respect key quality principles;
- **CONTACTS WITH PROVIDERS AND INSTALLERS AND CONTRACTING OF WORKS**: standardised pre-contractual arrangements between involved local actors will be established in order to speed-up the overall contracting process and facilitate subsequent interactions between the project owner and the Turnkey Retrofit service operator (e.g. single payment for the overall operation);
- **STRUCTURING AND PROVISION OF FINANCIAL INCENTIVES**: homeowners, or board of co-owners will be guided / directed to the most appropriate available financing opportunities;
- **MONITORING/ ONSITE COORDINATION OF WORKS AND QUALITY ASSURANCE**: to ensure quality control, quality assurance and integration of subcontractors. Turnkey Retrofit will use an ICT platform where stakeholders involved in the operation can share, view and manage their tasks in a safe and secure environment, using real-time information directly from the field via mobile apps;

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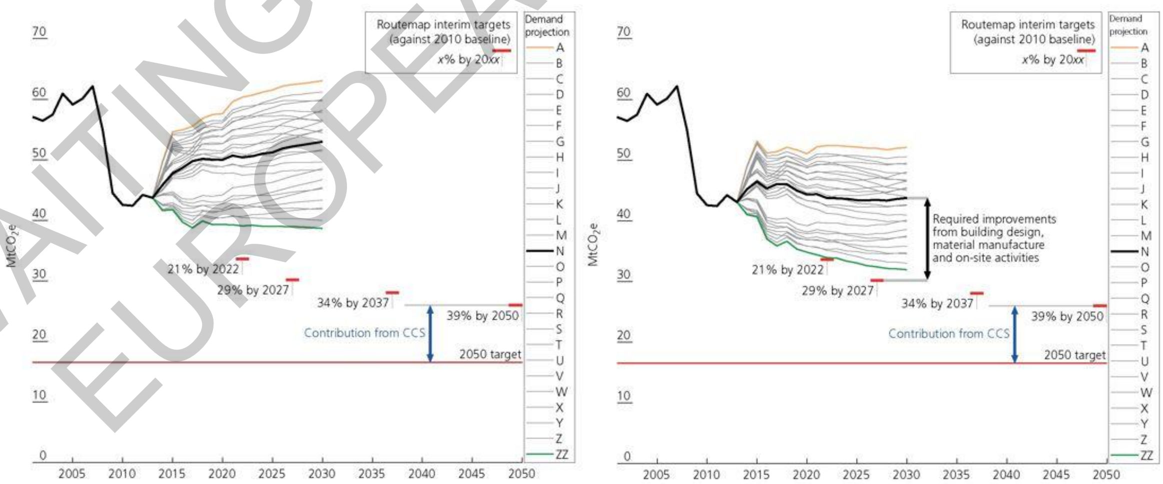
Turnkey Retrofit Service	
• **COMMISSIONING AND POST-ASSESSMENT OF THE WORKS AND OF THE BUILDING PERFORMANCE**: project owners will be invited to promote and share details of their renovation and feedback on the digital platform.	
CO-BENEFITS	• Reduce GHG emissions • Boost local business (km 0) • Increase employment rate and jobs • Decrease future maintenance costs • Improve land-use management • Enhance attractiveness of the cities • Reduce ecological footprint
KEYWORDS	It is directly connected with other solutions such as One-stop-shops and all other solutions related to building renovation, including instruments.
EXTERNAL LINKS	• A Turnkey Retrofit Solution for Single-family and Multi-family buildings Renovation (Turnkey Retrofit EU, Solutions4renovation) • Turnkey Retrofit EU, Solutions4renovation Demo VIDEO

3.8.36 Integrated Energy and GHGs scenario mapping tools

- Authors: **METABOLIC**
- Knowledge Repository link: **https://netzerocities.app/resource-1853**

Integrated Energy and GHGs scenario mapping tools
Cities are showing an increasing willingness to implement **energy-saving plans**. **Integrated energy and GHG scenario mapping tools** can support cities in this attempt. They can help to **reduce energy consumption**, maximize **energy efficiency**, and achieve science-based **emission reduction targets**. Mapping energy and gas consumption and determining energy demands, for example, helps to optimize energy supply systems. This can be done using **Geographic Information System (GIS)** as a helpful tool, such as in the case of Glasgow. In other cases, combining energy consumption mapping with the mapping of the state of the city's buildings can help to assess potential energy savings.
Source: Scenario analysis of embodied greenhouse gas emissions in UK construction (*https://doi.org/10.1680/jensu.16.00020*)
Next to using GIS as a mapping tool, other tools can help cities to assess integrated **energy and GHG scenarios**, define a strategy, and answer operational questions (number, age, energy consumption and GHGs impact, etc.) of buildings to renovate to achieve carbon neutrality. **LEAP**, for example, is a scenario-based modelling tool for energy policy analysis and climate change mitigation assessment,

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Integrated Energy and GHGs scenario mapping tools	
which can help governments to track energy consumption, production and resource extraction in all sectors of an economy. Another tool, **EnergyPLAN**, conducts advanced analyses of energy systems by simulating their operations on an hourly basis.	
CO-BENEFITS	Integrated Energy and GHG Scenario mapping tools help cities first and foremost to **reduce their energy needs** and thereby also **reduce GHG emissions**. An indirect co-benefit of reduced GHG emissions is the **improvement of air quality** in the city. As the tools help planners to develop a better understanding of the city's current energy needs, they can also lead to **increased skill development** among professionals.
KEYWORDS	It has direct connection with other solutions such as Integrated planning and strategies (from planning instruments); as well as it is related to other digital solutions such as Predictive Modelling or Scenario-based analysis.
EXTERNAL LINKS	• LEAP: Low Emissions Analysis Platform (https://leap.sei.org/) • EnergyPLAN (https://www.energyplan.eu/) • ENERKAD (Tecnalia) • Sympheny (https://www.sympheny.com/)

3.8.37 NBS and Green Infrastructure Mapping

- Authors: **METABOLIC**
- Knowledge Repository link: **https://netzerocities.app/resource-1863**

NBS and Green Infrastructure Mapping	
Green Infrastructure (GI) refers to a strategically planned network of natural and semi-natural spaces. In urban environments specifically, GI serves as a nature-based solution which is multi-functional and economically and socially sustainable, compared to grey infrastructure. GI provides **clean air and water and carbon storage**, enhances **biodiversity** and wildlife, and helps cities with **climate change adaptation** attempts. Planning new GI projects and maintaining existing GI in urban environments requires a clear identification and understanding of GI elements in place. Using **Geographic Information System (GIS) Mapping technology** can assist in the mapping of existing GI and can help decision makers and governments in incorporating GI into local area development and plan making. It can help to **identify areas** that are particularly prone to climate change consequences such as floods and droughts, and can also assist with the analyses of existing ecological networks. Specific tools can help to make sense of complex individual **environmental and socio-economic datasets** providing information on the natural capacity and resources in a specific region.	
CO-BENEFITS	Mapping GI infrastructure to accelerate the development of urban NBS has clear indirect and co-benefits: while in the first place the tools help to make sense of the current state of Green Infrastructure at hand, using them to advance GI can help cities to **reduce risks to natural and climate hazards** and to **enhance the stability of urban infrastructure**. In the wider sense, GI mapping can therefore also indirectly help to enhance the attractiveness of cities, reduce pollution, reduce noise pollution, and reduce hot spots/urban heat islands in the city.
EXTERNAL LINKS	• Green Infrastructure Mapping and Analyses Database, by GI Framework, England • GI Mapping for Local Infrastructure (Designated Sites, Natural England)

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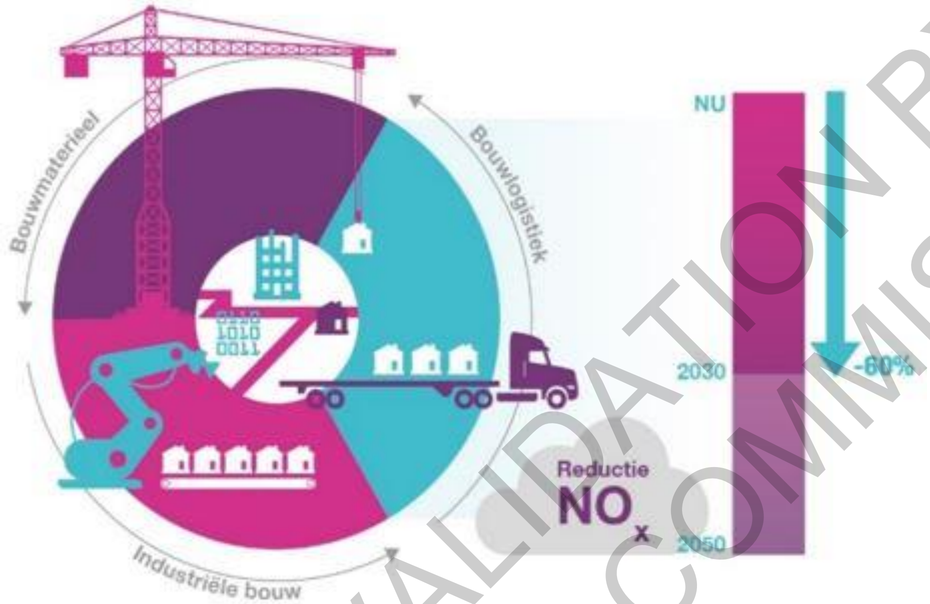
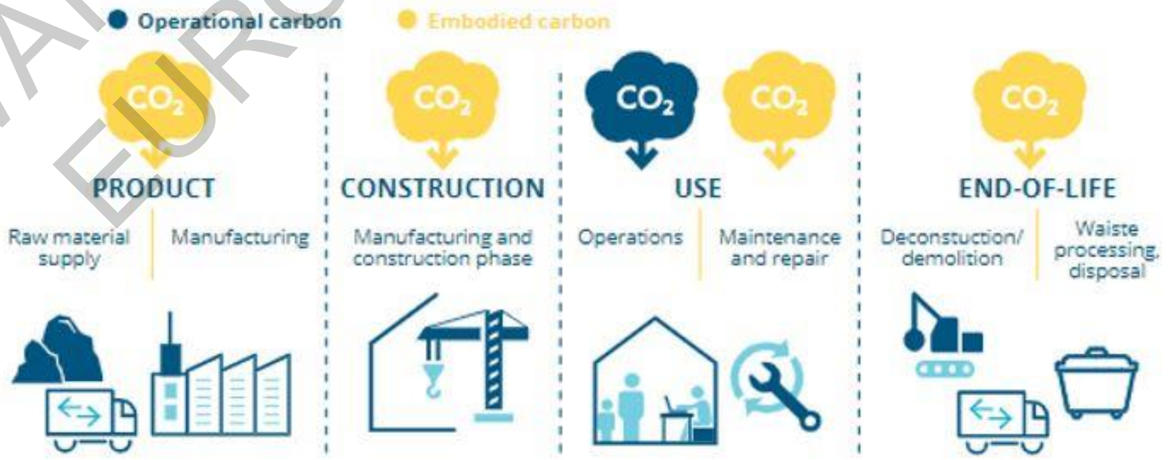
This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

3.8.38 Analysis of City/ (Building) circularity

- Authors: **TNO**
- Knowledge Repository link: https://netzerocities.app/resource-1873

Analysis of City/ (Building) circularity
Emission-free building systems is a method to clarify the impact of material-related energy of built objects, aiming at realizing a number of improvements, such as stronger quality assurance, faster construction time, greater productivity and an improved margin. Industrialization, due to reduced activities on the building site, more efficient production in the factory and optimized logistics, is also expected to contribute to emissions reduction.

Source: TNO (Link)
On the basis of a **Life Cycle Assessment (LCA)**, emissions from building systems, such as on-site construction, 2D or 3D unit construction are compared in terms of production, construction, maintenance, demolition and reuse. The focus is on emissions of CO2, NOx and particulates and a distinction is made between relevant building components, such as construction, interior, installations or facade systems. The method results in the **impact of building system modifications** at the level of **materialization** (e.g. bio-based or secondary), **construction methodology** (e.g. through industrial construction) and **logistics of processes** (e.g. through the use of construction hubs).

Source: BPIE (Buildings Performance Institute Europe), 2021

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Analysis of City/ (Building) circularity	
A distinction is made between the **overall lifecycle emissions** and the **local emissions at the construction site**. This not only provides general insights into emission-controlled construction methods, but also stimulates locally short, healthy and circular construction processes in cities.	
CO-BENEFITS	This solution could improve air quality, reduce risk to natural and climate hazards, enhance stability of the urban infrastructure, reduce energy needs, increase carbon sequestration capacity (explaining that this through indirect solutions such as NBS), increase technological readiness, decrease future maintenance costs, contribute to better waste management, promote the materials cycle, reduce noise pollution, aid in reduction of road danger, enhance attractiveness of the cities, and offer better access to living areas for all, as well as reduce ecological footprint.
KEYWORDS	It has direct connection with solutions such as Urban mining model to assess circular construction opportunities and optimize resource use and exchange; Circular Life Cycle Cost (C-LCC) for deep renovation; Circular economy design principles to increase the durability, reparability, upgradability or reusability of products; Urban metabolism mapping; Circular Life Cycle Assessment/Analysis for material and products; or Building material passport (BIM-based).
EXTERNAL LINKS	• Whole-life Carbon: Challenges and solutions for highly efficient and climate-neutral buildings (BPIE: Buildings Performance Institute Europe) • Construction and demolition waste: challenges and opportunities in a circular economy (EEA: European Environment Agency) • Greater circularity in the buildings sector can lead to major cuts in greenhouse gas emissions (EEA: European Environment Agency)

3.8.39 Circular economy design principles to increase the durability, reparability, upgradability or reusability of products

- Authors: **CKIC, CARTIF**
- Knowledge Repository link: **https://netzerocities.app/resource-1883**

Circular economy design principles to increase the durability, reparability, upgradability or reusability of products
Design specifications are non-binding rules used by diverse teams. They can be issued by both public and private entities and are applicable to different actors depending on their roles. Developing and sharing a (local) set of guidelines can support the **transformation of the market towards embodied carbon neutral products**. The efficacy of the guidelines shall be strengthened through inclusion in tender and procurement processes. The guidelines can also be used by financial actors as a basis for the development of performance-based financing.

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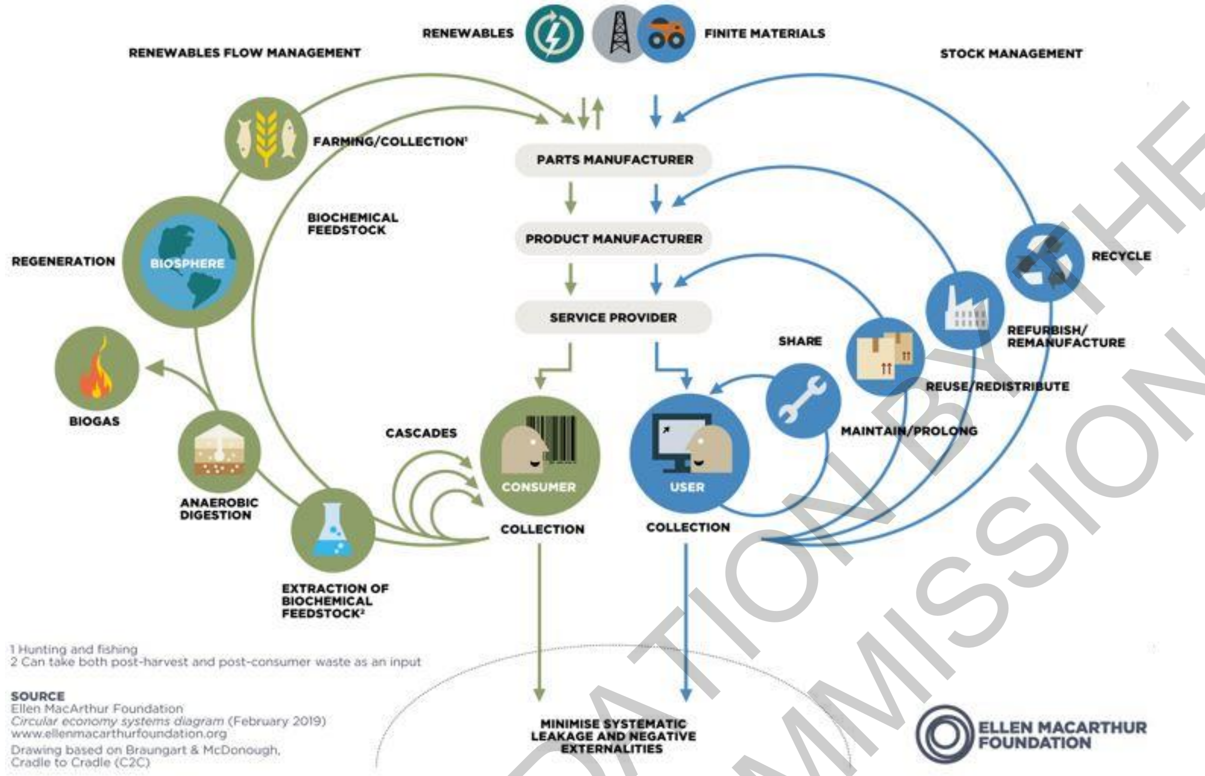
Circular economy design principles to increase the durability, reparability, upgradability or reusability of products



Source: Ellen MacArthur Foundation

There is no need to reinvent the wheel: existing **guidelines** can be integrated with various resources to generate updated guidelines and specifications which are conducive to **circularity**. For example, the European common framework **Level(s)**, based on a review of scientific literature by the Joint Research Centre, highlights the following design concepts for targeting hot spots for environmental impact:

- **Efficient design**: Optimize the design in order to improve material efficiency and minimise energy use.
- **Optimised material utilisation and circular value**: Consider feasibility of reusing existing elements, designing for minimal material use, minimizing waste generation during product manufacturing and construction.
- **Extended service life**: Consider options to extend the lifespan of significant components and to minimize the number of replacement and renovation cycles.
- **Design for adaptability**: Consider the potential of the design to adapt and be flexible to changing needs.
- **Design for deconstruction**: Consider how the design and information records about the project material bank can facilitate future end of life deconstruction in order to recover materials for reuse and recycling.

CO-BENEFITS	• Increase technological readiness • Decrease future maintenance costs through easier retrofit • Increased skill development • Better waste management • Promote the materials cycle • Reduce ecological footprint (indirect effect of the application of this solution)
KEYWORDS	It has direct connection with solutions such as Optimal management of waste at the end of building life cycle; System level circular economy approaches in batteries; Passive building design strategies; Circular Packaging; Circular Life Cycle Assessment/Analysis for material and products; or Urban mining model to assess circular construction opportunities and optimize resource use and exchange.

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Circular economy design principles to increase the durability, reparability, upgradability or reusability of products	
EXTERNAL LINKS	• Circular Design: turning ambition into action (Ellen MacArthur Foundation) • The Circular Design Guide Specific to buildings and construction: • Elliott Wood has produced a detailed guide on the deconstruction of buildings for circular re-use • The EU's Urban Agenda Partnership on Circular Economy has published the Sustainable Circular Reuse of Spaces and Buildings Handbook to guide the transformation and reuse of existing buildings and spaces • FutureBuilt Criteria for Circular Buildings - FutureBuilt is an alliance of Norwegian partners for future-proof construction, led by the City of Oslo (in Norwegian)

3.8.40 Urban metabolism mapping

- Authors: **METABOLIC**
- Knowledge Repository link: **https://netzerocities.app/resource-1893**

Urban metabolism mapping
Cities' metabolism is the process of converting **material inputs into outputs**. Urban metabolism mapping is a method of quantifying and visualizing all the energy and material flows entering the city to meet the needs of the city and assessing how these materials are either stored or transformed and how they are exiting the city. Transitioning from the prevalent linear urban metabolism to a **circular urban metabolism** is essential to achieve environmental sustainability. The current linear metabolism converts resources into waste that is discharged into the environment. A circular metabolism allows for better resource use efficiency. To **design waste out of our urban systems**, a clear understanding of current **material flows** is essential. Urban metabolism mapping practices can help cities in their attempt to identify product streams and material inputs and thereby establish a clear picture of the urban material flows. From there, more in-depth analysis can be conducted and circular interventions can be designed and implemented to promote closed-loop systems.

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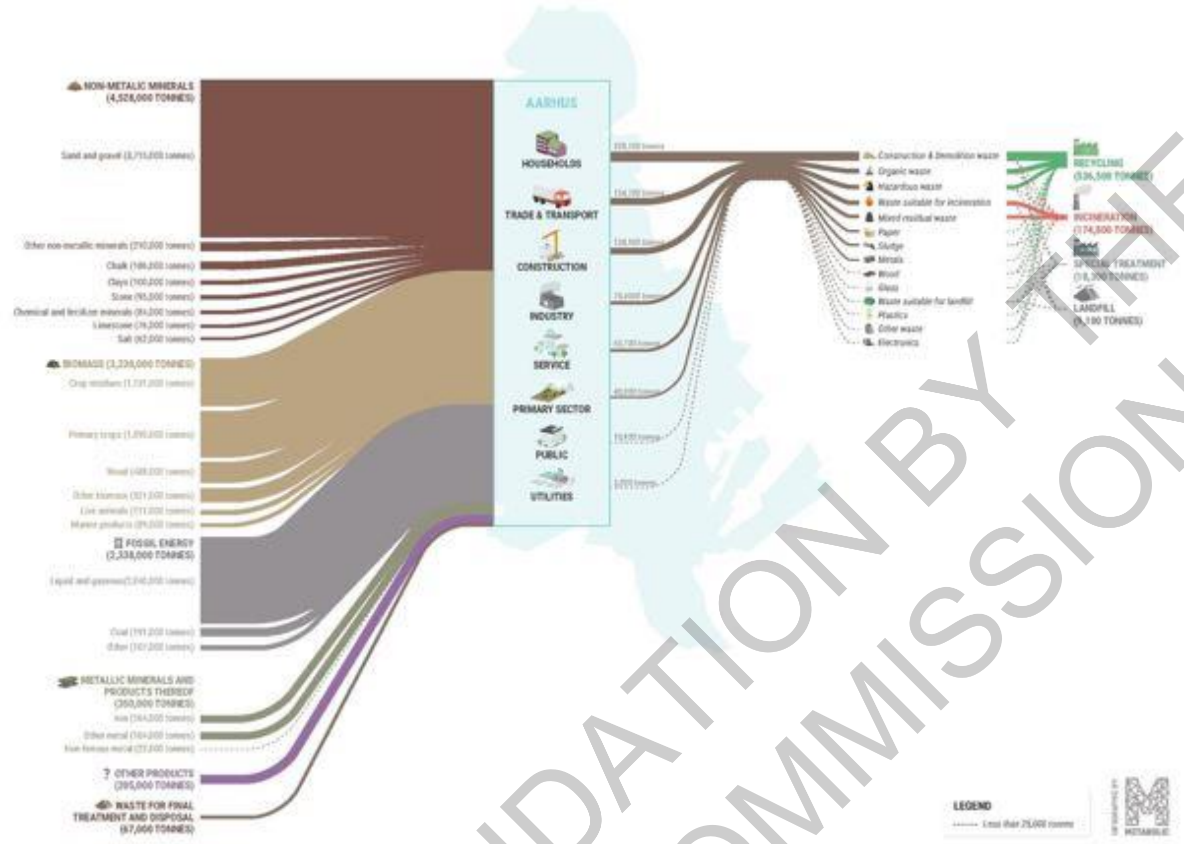
Urban metabolism mapping



Source: Metabolic

A commonly used practice to assess these streams is by conducting a **Material Flow Analysis**. Using this approach, the materials flowing into the urban system, the stocks within the system, and the outputs are identified and can be visualized by means of e.g. Sankey diagrams.

CO-BENEFITS	Urban Metabolism Mapping can be used as a tool to design closed-loop, circular urban systems and can have several co-benefits. By gaining a better understanding of the material flows, **resource use efficiency** can be maximized. This can help to **reduce energy needs** and **reduce GHG emissions**. On an economic level, designing out waste in the attempt to rewire material flows can promote both a **sharing economy** and **proximity economy**. It can also help to promote the materials cycle and lead to better waste management as well as better water management. Finally, designing circular systems within a city following a Material Flow Analysis can help to create **sustainable and resilient food systems** and **reduce food waste**.
KEYWORDS	It has direct connection with solutions such as Urban mining model to assess circular construction opportunities and optimize resource use and exchange; Circular Life Cycle Cost (C-LCC) for deep renovation; Analysis of City/(Building) circularity; Circular economy design principles to increase the durability, reparability, upgradability or reusability of products; Circular Life Cycle Assessment/Analysis for material and products; or Building material passport (BIM-based).
EXTERNAL LINKS	• REFLOW: https://reflowproject.eu/ • UrbanWINS: https://www.urbanwins.eu/ • Roadmap for a Circular Resource Efficiency in cities (EC)

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This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

3.8.41 Circular Life Cycle Assessment/Analysis for material and products

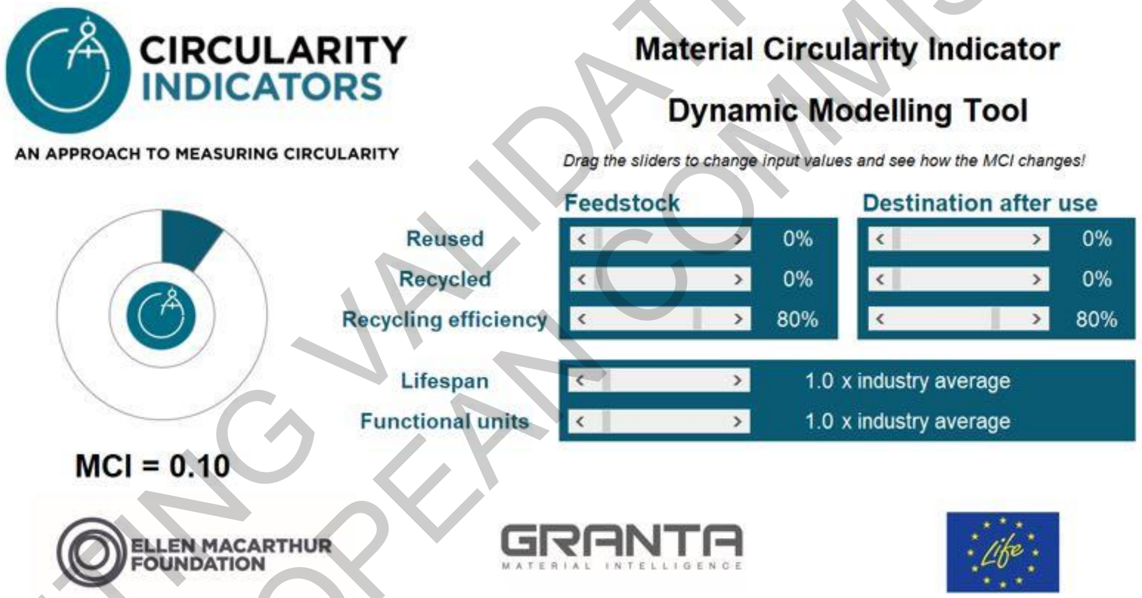
- Authors: **CKIC**
- Knowledge Repository link: https://netzerocities.app/resource-1903

Circular Life Cycle Assessment/Analysis for material and products

Life Cycle Analysis (LCA) is a type of due diligence that can be performed for materials and products, but also other 'systems': projects, corporations, or cities. LCA can assist in:

- **identifying opportunities** to improve the environmental performance of the selected system at various points in their life cycle,
- **informing decision-makers** in industry, government or non-government organizations (e.g. for the purpose of strategic planning, priority setting, product or process design or redesign),
- **marketing** (e.g. implementing an ecolabelling scheme, making an environmental claim, or producing an environmental product declaration).

A **circular LCA** addresses the potential environmental impacts (e.g. use of resources and the environmental consequences of releases) throughout a **system's life cycle**: from raw material acquisition through production, use, end-of-life treatment, (Modules A to C of standard EN 15978) and beyond it, to recycling/ refurbishing/ remanufacturing, etc.



This is part of the Circularity Indicators Project by the Ellen MacArthur Foundation and Granta Design Ltd (co-founded by the EU's Life programme)

Circular LCA also includes **circularity indicators**, such as recycling and reusing rates. Circularity indicators are beneficial to mitigate risks from material price volatility and material supply. There is as yet no standard methodology for circular LCA. The European Commission is leading efforts in this direction.

CO-BENEFITS	• Improved access to information • Raised awareness/behavioural change • Increased skill development • Better waste management • Promote the materials cycle • Reduce risk to natural and climate hazards through early detection of e.g. exposure to material scarcity • Reduce ecological footprint

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This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

Circular Life Cycle Assessment/Analysis for material and products	
KEYWORDS	It has direct connection with other solutions such as Urban mining model to assess circular construction opportunities and optimize resource use and exchange, Circular Life Cycle Cost (C-LCC) for deep renovation; Analysis of City/(Building) circularity; Circular economy design principles to increase the durability, reparability, upgradability or reusability of products; Urban metabolism mapping; or Building material passport (BIM-based).
EXTERNAL LINKS	• Which indicators are used to monitor the progress towards a circular economy? (Eurostat) • Material Circularity Indicator (MCI), Ellen MacArthur Foundation • One Click LCA: automated life cycle assessment software that helps users calculate and reduce the environmental impacts of building and infrastructure projects, products and portfolios. • **Level(s)** European framework for sustainable buildings • Guidelines on reporting climate-related information (EC) • Inventory Circular Economy Indicators (OECD)

3.8.42 One-stop-shop for building renovation

- Authors: **Energy Cities**
- Knowledge Repository link: **https://netzerocities.app/resource-1913**

One-stop-shop for building renovation
One-stop shop is a collective term for services offering **integrated renovation solutions** with the main intention of simplifying the renovation process for homeowners. A one-stop-shop is a virtual and/or physical place where homeowners can find **all information and services** they need to implement an ambitious global energy renovation project. One-stop shops can play roles as facilitators in the Renovation Wave, by interconnecting funding opportunities, incorporating solutions to new regulatory requirements, organising training and apprenticeship programmes and supporting various awareness-raising activities.

Source: INNOVATE project, Energy Cities

In order to increase the renovation rate in one defined area, the one-stop-shop needs to cover the following **services** and propose them, ideally, 'under one roof':

- **Proactive engagement of homeowners**: market segmentation, targeted communication and marketing tools are a key to reach out to the right groups at the right moment (e.g. young families, elderly people, low-income households, etc.) with the right message.
- **Energy renovation and financial plans**: These tailor-made plans should aim at achieving deep renovation, depending on the financial means of each homeowner.

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One-stop-shop for building renovation	
• **Coordination of the renovation process** on behalf of the homeowner. • **Long-term and affordable financing**: especially for low and medium income families, elderly people and other vulnerable groups who cannot access other financing means although the value of their energy savings is large enough to pay off. • **Guaranteed results and post-work monitoring** including of the quality of works and, ideally, energy savings	
CO-BENEFITS	• Reduce energy needs • Improved access to information • Raised awareness/behavioural change
EXTERNAL LINKS	• Underpinning the role of One-Stop Shops in the EU Renovation Wave, BPIE, 2021 • How to set up a one-stop-shop for integrated home energy renovation: A step-by-step guide for local authorities and other actors, INNOVATE project, Energy Cities, 2020

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4 Concepts

A concept is a principle or an idea, which supports climate neutrality city targets, that can combine several solutions together.

A couple of workshops were organised in the context of WP10 on this, the first one to brainstorm on concepts we found relevant to be added in the Knowledge Repository as additional/complementary information to the bunch of developed solutions. Then, second workshop was focus on prioritise them to select the ones to be developed, with the result of the list in Table 11. Such prioritisation took into account the ones that had more connections and seem to be of the utmost relevance.

- **Knowledge Repository: Concepts that support climate neutrality city targets (combine several solutions together): https://netzerocities.app/resource-3228**

Table 11: Concepts

Concepts prioritised	Thematic Area	Section
GHG emissions / Scope 1, 2 & 3	*ALL*	**4.1.1**
Carbon Dioxide Removal (CDR) / Negative emissions	Green Industry Nature-based Solutions	**4.1.2**
Urban heat island (UHI) effect mitigation - Nearly Zero Energy Buildings (NZEBs)	Stationary Energy Energy Generation	***JRC**
Near Zero/ Positive Energy Districts (PEDs)	Stationary Energy Energy Generation	***JRC**
Positive Energy Buildings (PEBs)	Stationary Energy Energy Generation	***JRC**
Eco-districts / Green neighbourhoods	Stationary Energy Energy Generation	**4.1.3**
Urban heat island effect mitigation – Evaporate Cooling	Energy Generation	***JRC**
Smart Grid	Digital Solutions	**4.1.4**
15-minute city	Mobility and Transport Enabling Instruments	**4.1.5**
Industrial symbiosis	Green Industry Circular Economy	**4.1.6**
Water-Energy-Food-Ecosystem (WEFE) Nexus approach	Circular Economy	**4.1.7**
Urban green space ecology	Nature-based Solutions	**4.1.8**
Carbon capture and storage (CCS) and utilisation (CCU)	Green Industry Circular Economy	**4.1.9**

As can be seen in the table, some of the concepts were already covered by the JRC, so only the link to them in the Knowledge Repository is provided below instead of had their own section in this deliverable (as they have not been developed by the WP10 team):

- Urban heat island (UHI) effect mitigation - Nearly Zero Energy Buildings (NZEBs): https://netzerocities.app/resource-3364
- Near Zero/ Positive Energy Districts (PEDs): https://netzerocities.app/resource-3354
- Positive Energy Buildings (PEBs): https://netzerocities.app/resource-3374
- Urban heat island effect mitigation – Evaporate Cooling: https://netzerocities.app/resource-3384

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4.1.1 Concept: GHG emissions / Scope 1, 2 & 3

- Authors: **METABOLIC**
- Knowledge Repository link: **https://netzerocities.app/resource-3238**

Concept: GHG emissions / Scope 1, 2 & 3
Greenhouse gas (GHG) emissions are gaseous constituents of the atmosphere, both natural and anthropogenic. Water vapour (H2O), carbon dioxide (CO2), nitrous oxide (N2O), methane (CH4) and ozone (O3) are the primary GHGs in the earth's atmosphere. Moreover, there are a number of entirely human-made GHGs in the atmosphere, such as the halocarbons and other chlorine- and bromine containing substances (source). GHG emissions caused by human activities - also called anthropogenic emissions - as defined by the GHG Protocol (one of the largest GHG monitoring methodologies) are divided by three types of levels, namely scope 1, scope 2 and scope 3. This scopes framework helps to differentiate emissions occurring physically within a city (scope 1), from the use of electricity, steam, and/or heating/cooling supplied by grids (scope 2), and from emissions occurring outside of the city (scope 3) (source). There has been an increased interest to include all three scopes in the cities' inventories. Especially scope 3 has gained increased significance as up to 85% of the emissions associated with goods and services consumed in cities are generated outside the city (source). Another way of differentiating GHG emissions as defined by PAS20:70 methodology (another well-known GHG monitoring methodology) are direct plus supply chain emissions (DPSC) and consumption-based emissions (CBE). The DPSC method focuses on GHG emissions from activities within the city boundary and indirect emissions from the consumption of grid-supplied electricity, heating and/or cooling, transboundary travel and the supply chains from the consumption of goods and services produced outside the city boundary (e.g., food and building materials). The CBE methodology includes all direct and life cycle GHG emissions for all goods and services as consumed by residents of a city. GHG emissions are thus allocated to the final consumers of goods and services, rather than the original producers of those GHG emissions. Products and services that are exported for consumption outside of the city boundary are therefore not part of this calculation (source). Scope 3 emissions and consumption-based emissions have often been used interchangeably as they both project the emissions that occur outside of the city boundary. However, there is a difference between the two types which is important to delineate. Scope 3 emissions are emissions that are always outside the city, associated to activities inside the city but not necessarily direct consumption: such as embedded emissions of building material production being used in the city, but produced elsewhere. Consumption based emissions focus on the consuming activities of the residents of the city at hand. These are activities that happen within the city boundary but also if a resident would be on holiday in a different country. ***Setting the inventory boundary*** The inventory boundary identifies which gases, geographic area, emissions sources and time sources are covered by the GHG inventory. It is crucial that the setting of a boundary remains consistent over time to make an inventory comparison across different years. As well as, potentially making comparisons between (NZC) cities and creating an international benchmark.

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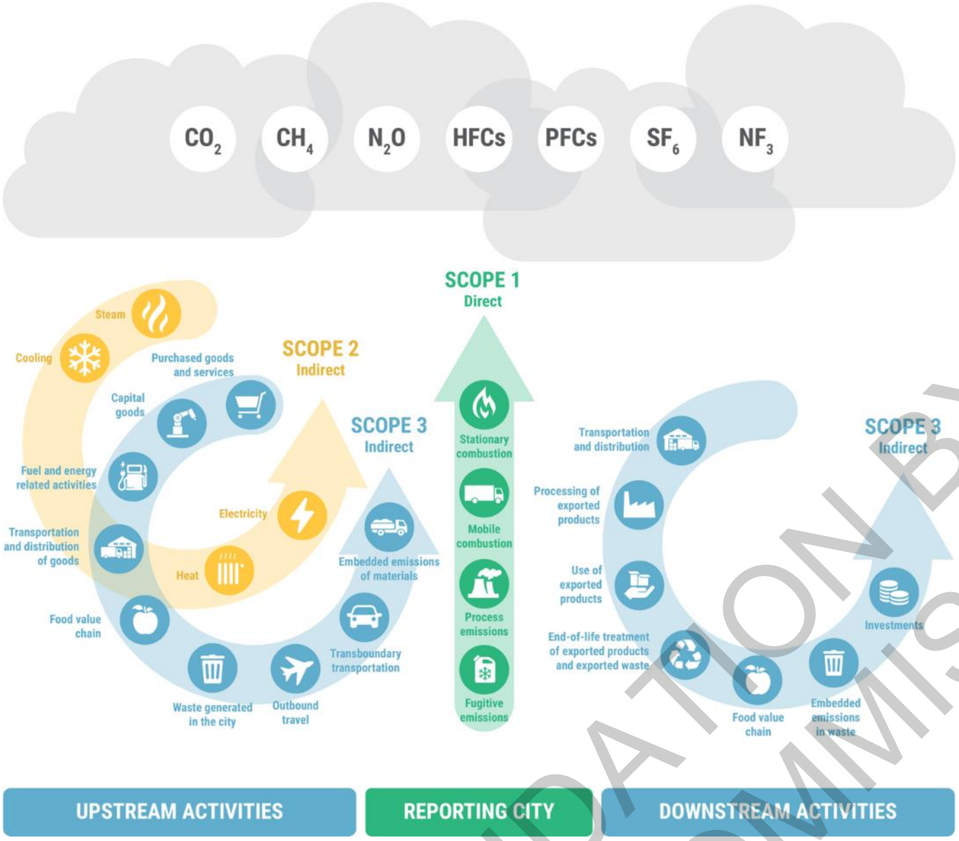
Concept: GHG emissions / Scope 1, 2 & 3	
 Picture from D2.4.1	
CO-BENEFITS	By understanding and monitoring GHG emissions cities will be able to gain a clear insight into their biggest sources of emissions. In this way, cities are able to draft more designated action plans to reduce large sources of emissions. Monitoring GHG emissions can also create more citizen awareness, especially when there is a focus on consumption-based emissions. Citizens will gain an insight into their (polluting) behaviours and can behave accordingly.
EXTERNAL LINKS	• GHG Protocol for Cities • CDP-ICLEI Track climate disclosure platform • Covenant of Mayors • 2019 Refinement to the 2006 IPCC Guidelines on National Greenhouse Gas Inventories
EXAMPLES	• C40 Portland case study

Concept: GHG emissions / Scope 1, 2 & 3	
PRE-CONDITIONS & ENABLING CONDITIONS	***Technical aspects/infrastructure:*** Data availability for different sectors which have been gathered structurally over the last years to be able to calculate emissions. ***Funding and financing:*** It takes time and expertise to gather data and monitor the emissions of a city. Ideally the city hires dedicated data analysts to make these assessments. ***Policy and regulatory/legal framework:*** Ensuring mandatory monitoring of emissions as well as international frameworks/benchmarks to have a coherent mode of establishing an inventory for every city.

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Concept: GHG emissions / Scope 1, 2 & 3	
CONSTRAINTS/ BARRIERS for implementation	The availability of data Having enough expertise and designated analysts to monitor emissions
INSTRUMENTS/ Processes for implementation	• Integrated Energy and GHGs scenario mapping tools: https://netzerocities.app/resource-1853 • Supporting municipalities to monitor resource flows in line with impact targets and measurement processes: https://netzerocities.app/resource-1528 • Building Material Passport (BIM-based): https://netzerocities.app/resource-1833
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	If cities only manage to gather partial data and create an incomplete inventory, it could create a skewed perception of their progress. As for now, many cities have yet to find standardized outlines on how to make a complete inventory including scope 1, 2 and 3 emissions.
IMPACTS (Indicators & DNSH)	Scope 1 in MtCO2eq, Scope 2 in MtCO2eq, Scope 3 in MtCO2eq
	DNSH: ***Climate change mitigation:*** If an incomplete/partial inventory of a city is compiled, it could give a skewed perception of progress. This could for instance give the idea that a city is making progress while it isn't or create focus on certain sectors whilst they aren't the biggest emitters.
Additional information from CASE STUDIES	• C40 GHG emissions resource center

4.1.2 Concept: Carbon Dioxide Removal (CDR) / Negative emissions

- Authors: **South Pole**
- Knowledge Repository link: **https://netzerocities.app/resource-3248**

Concept: Carbon Dioxide Removal (CDR) / Negative emissions
Carbon dioxide removal (CDR) is the process of capturing carbon dioxide (CO_2) from the atmosphere and permanently storing it in plants, soils, oceans, geological features, or long-lived products like cement, where it can be locked away for decades or centuries – this results in a negative emission. Negative emissions can be achieved through a wide-array of approaches, both technological and nature-based. ***Technological removal approaches include:*** • **Direct Air Capture and Storage (DACS)** is the removal of CO_2 directly from the atmosphere, using scrubbers and chemical processes, and storage underground or in products. • **Bioenergy with Carbon Capture and Storage (BECCS)** is the process of using biomass to generate energy for industrial, power or transportation purposes, capturing the emissions before they are released in the atmosphere and permanently storing the captured carbon underground or in long-lived products. This technology can provide net carbon removal if it leads to more biomass growth than it would normally occur, or if more carbon is stored than being released back into the atmosphere. Biomass with Carbon Removal and Storage (BiCRS) is a related approach, which involves the permanent storage of any carbon emissions from biogenic emissions (including biogas plants, biomass plants, waste combustion plants and wastewater treatment plants). ***Most prominent nature-based removal practices are:***

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Concept: Carbon Dioxide Removal (CDR) / Negative emissions

- **Soil carbon sequestration** (also known as carbon farming or regenerative agriculture): the sum of land management practices that enable soils to absorb and hold more carbon.
- **Afforestation/ reforestation:** storing CO_2 in newly grown or re-grown forests.
- **Enhanced mineralisation** (also known as enhanced weathering or accelerated weathering): accelerating the natural process through which certain minerals capture CO_2 from the atmosphere.
- **Ocean-based CDR:** amplification of the ocean's capacity to absorb and store CO_2 from the atmosphere.

CDR is different from point-source carbon capture from the fossil power sector and heavy industry, with the key distinction being that CDR is targeting CO_2 that is already in the atmosphere (including via biomass), while conventional CCS captures the carbon from fossil fuel combustion at the point-source, before it has entered the atmosphere.

Most credible pathways compatible with the 1.5 degrees temperature goal of the Paris Agreement require the use of carbon dioxide removal (CDR). While CDR cannot replace emission reductions, it fulfils three crucial roles:

1. reducing CO_2 emissions levels in the short-term;
2. counterbalancing residual emissions from hard-to-abate sectors in order to reach net zero CO_2 in the medium-term; and
3. achieving net negative CO_2 emissions in the long-term.

CDR capacities will need to grow significantly. CDR is an integral part of a net-zero transition – the IPCC estimates that 1.9–16.1 $GtCO_2$ of removals will be required annually by 2050 to reach net zero. Negative emission technologies, notably biomass energy with carbon capture and storage (BECCS) and direct air capture and storage (DACS), will therefore be required at scale to achieve net-zero- and 1.5-degree goals. However, their current adoption rates remain very low.

Both nature-based and technological removals play an important part in cities' net-zero strategies. Nature-based solutions adapted to cities, such as increasing public green spaces, community gardens and green roofs also have the benefit of reducing air pollution and improving wellbeing. However, due to the limited available land in cities or in their immediate proximity, cities would also have to rely on engineered removals to achieve their targets. The use of technology-based CDR solutions in cities net-zero strategies would not only support the achievement of their own target, by providing measurable, durable removals, but would also send a strong signal of support for these technologies. Public funding is a critical element in scaling up these innovative technologies, seen as essential for meeting our climate goals.

CO-BENEFITS	***For technological removals:*** • Potential reduction of local air pollution; • Job conversion and job creation; • Reduced land-use needs, minimising impacts on food production and other land-uses; • BECCS is the only CDR technique that also provides energy. ***For nature-based removals:*** • Enhanced biodiversity and ecosystem functions • Improved local employment and livelihoods • Increased wellbeing in local communities, improved community links and engagement
KEYWORDS	• Negative emissions • Engineered removals • Carbon removals • Carbon sinks • Net-zero emissions • Carbon neutrality • Cdr approaches • Cdr solutions • Nature-based removals

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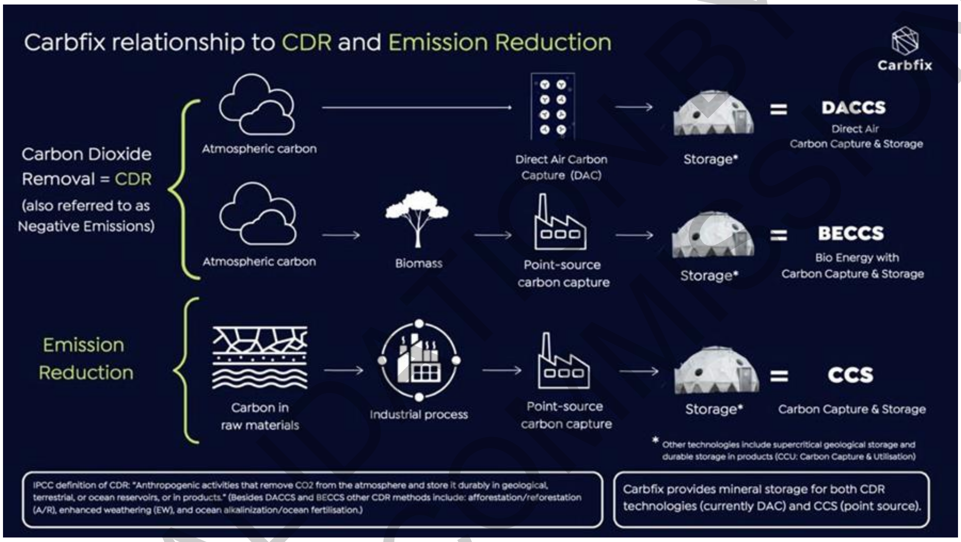
<table>
<tr><th colspan="2">Concept: Carbon Dioxide Removal (CDR) / Negative emissions</th></tr>
<tr><td></td><td>

- Nature-based solutions
- Community projects
- Public green spaces
- Air pollution
- Atmospheric carbon concentration
- Land-management

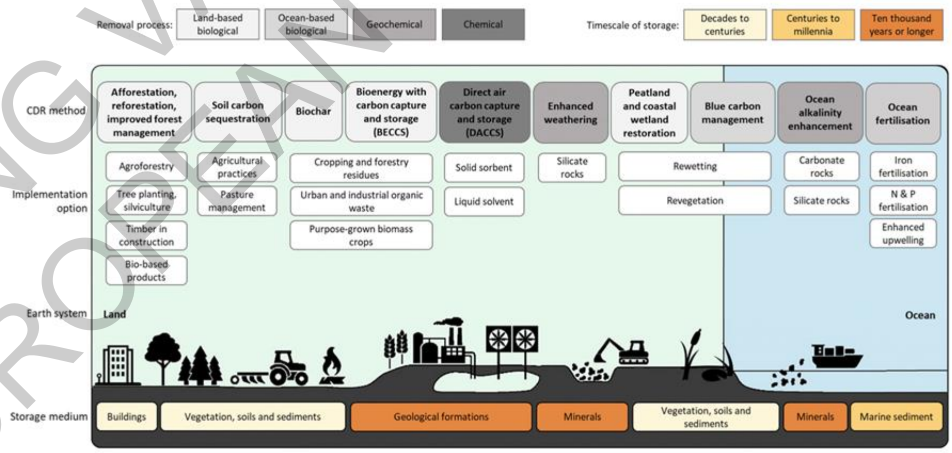
</td></tr>
<tr><td>EXTERNAL LINKS</td><td>

Links provided in the footnotes

- https://carbon180.org/fact-sheets
- https://cdrprimer.org/
- https://www.frontiersin.org/articles/10.3389/fclim.2022.884163/full
- https://co2re.org/what-is-ggr/



Carbfix 2022



IPCC (2022) Cross-Chapter Box 8, Figure 2

</td></tr>
<tr><td>EXAMPLES</td><td>

Projects:

- Stockholm - World's first urban carbon sink with biochar: https://www.c40.org/case-studies/cities100-stockholm-world-s-first-urban-carbon-sink-with-biochar/
- City of London - Using open spaces to remove carbon: https://www.cityoflondon.gov.uk/services/environmental-health/climate-action/climate-action-projects/using-open-spaces-to-remove-carbon
- Large-scale BECCS facility in Stockholm's Vartan neighbourhood being planned by the city's utility company, Exergi: https://beccs.se/

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Concept: Carbon Dioxide Removal (CDR) / Negative emissions	
PRE-CONDITIONS & ENABLING CONDITIONS	***Technical aspects/infrastructure:*** BECCS is suitable for retrofitting existing bioenergy facilities, some of which (e.g. waste-to-energy plants, biomass district heating plants) are closely tied to essential local utility services. Sourcing sustainable biomass for energy generation is key to ensuring that these technologies lead to real, high-quality removals. DAC requires large amounts of energy to operate. Access to abundant renewable energy is an important element in maximising its climate impact and driving costs down. The IEA estimates that in locations with high renewable energy potential and using the latest technologies for power and heat generation, DAC costs could decrease below USD 100/tCO_2 by 2030. Synergies with existing economic activities present in cities and promoting a low carbon pathway for specific industries (ex: DACS for aviation, BECCS for timber users, pulp and paper companies). Current megaton DAC facilities, such as Climework's Orca plant in Iceland, and the soon-to-come online Carbon Engineering's plants in Scotland and in the U.S. Southwest are located in remote areas. However, innovative DAC projects are being explored, that either integrate smaller scale direct air capture within urban infrastructure, or retrofits existing infrastructure in ports to capture CO_2, that would be well suited to cities. ***Policy and regulatory/legal framework:*** The EU Commission's communication on Sustainable Carbon Cycles in 2021 states that achieving the EU climate-neutrality target would require between 300 Mt and 500 Mt of carbon dioxide removal from waste, sustainable biomass and directly from the atmosphere by 2050. The European Union is also in the process of developing its carbon removal certification scheme. This initiative aims to embed high quality requirements into the regulations, while acknowledging the role that carbon removals will play in the EU's pathway to carbon neutrality. However, too stringent regulatory requirements risk posing additional barriers to a sector still in its nascency. Breaking down net-zero targets at different governance levels to quantified targets per technology would make roadmaps more robust and credible and incentivize technology-specific support. Currently, no EU member state has a dedicated CDR strategy, and only Germany and Portugal have targets that differentiate between reductions and removals. ***Funding and financing:*** Inclusion of technology-based CDR in the EU Innovation Fund. Public support schemes from national governments. Advanced market commitments for CDR. Carbon finance revenues through voluntary carbon markets. European City Facility (EUCF) to finance the investment concepts. ***Project governance and implementation modalities:*** Public-private partnerships Stakeholder consultation and engagement
CONSTRAINTS/ BARRIERS for implementation	The current costs of engineering removals are significantly higher than those of nature-based removals, and of the average carbon prices in the EU. DACS costs are estimated at about USD 250–600 per ton of CO_2, depending on the technology, energy source, and scale of deployment. Absence of agreed high-quality standards, on critical aspects such as permanence, additionality, embodied carbon hinder early investments. Public awareness on the benefits of technology-based removals is low, and public investments in such technologies can be controversial, due to a common misconception that carbon removals divert attention away from mitigation

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Concept: Carbon Dioxide Removal (CDR) / Negative emissions	
	measures. An explanation on the complementarity of removals in meeting net-zero is needed to build citizen buy-in.
INSTRUMENTS/ Processes for implementation	• Decarbonization plans for industry: https://netzerocities.app/resource-1718 • Integrated climate plans for cities: https://netzerocities.app/resource-1698 • Governance EU climate neutrality framework: https://netzerocities.app/resource-1728
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	Risk of additionality principle not being respected in sourcing the biomass, undermining the climate benefits of the technology, and decreasing public support. Small scale DAC facilities not delivering the amounts promised, and risk of backlash from local communities. Risk of leakage and reversal in case of inadequate storage and transport. The risk of reversal is high in case of nature-based solutions, and monitoring and verification might prove challenging.
IMPACTS (Indicators & DNSH)	***GHG emissions:*** NbS can deliver emission reductions of at least 5 gigatons of CO_2 per year by 2030, and at least 10 gigatons by 2050. GHG emissions removed: 85 Mt of CO_2 in 2030 and around 980 $MtCO_2$ in 2050 captured through DAC in the IEA Net Zero Scenario (up from almost 0.01 $MtCO_2$ today). 250 Mt/year removed through BECCS by 2030 in the same scenario. ***Costs:*** Nature-based solutions can be as low as USD 0; the range for BECCS is USD 30 400 per ton, depending on the type of bioenergy. USD 250–600 per ton of CO_2 for DACS

4.1.3 Concept: Eco-districts / Green neighbourhoods

- Authors: **Tecnalia**
- Knowledge Repository link: **https://netzerocities.app/resource-3258**

Concept: Eco-districts / Green neighbourhoods
As it happens with some other subsets of sustainability term or its application (i.e.: climate-neutral city, smart-sustainable city), there is not unique and clear definition for the eco-district term. Generalist definitions describe an eco-district as an urban development aiming to deploy the objectives of sustainable development, focusing on integrating environmental, social and economic goals. However, there is also an innovative component in the way that urban development is developed; an urban experiment that tests cities' capacities to implement sustainability core elements in a limited urban area, and to do so through an integrated planning approach as the Leipzig Charter states. Regarding the transposition of the concept to real urban environments, cities and developers need pragmatic and systematic approaches to deploy the concept on-site, often resorting to the use of Neighbourhood Sustainability Assessment (NSA) frameworks. The most common certification schemes are: • DGNB System for Districts • Leadership in Energy and Environmental Design Neighbourhood Development (LEED ND) • Breeam Communities • HQE Aménagement (HQE A) • STAR Communities According to the study of these NSA frameworks, the development of eco-districts has to incorporate an improvement of sustainability standards on each of the following main themes: governance structure, built environment and public space, social and economic wellbeing, energy and climate, natural resources, transportation, and land-use.

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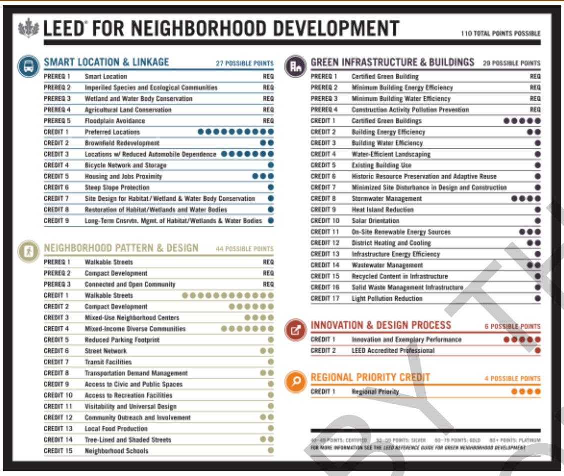
Concept: Eco-districts / Green neighbourhoods



Examples of Eco-district certification schemes. DGNB System for Districts and LEED for Neighbourhood Development.

THEMATIC AREA	Cross-cutting, potentially including all thematic areas
CATEGORIES	Integrated solutions
CO-BENEFITS	The scale (district) and sectoral integration (energy, green infrastructure, waste & water management systems, mobility, etc.) values embedded in the eco-district concept, they both bring multiple co-benefits attached to the deployment of such initiatives: ***Climate resilience:*** <u>Climate adaptation, enhance stability of the urban infrastructure</u>: Reduced risk to natural and climate hazards, heat waves and extreme climatic events, consequence of a climate-oriented design of the eco-district. The urban infrastructure is also benefited from this design approach at sectoral level (green infrastructure, water & waste management systems, electricity grid, heating & cooling distribution, etc.)." ***Environment:*** <u>Environmental risks mitigation: Reduced ecological footprint</u>: The use of energy conservation and renewable energies implemented in eco-districts, decreases the use of air conditioning and reduces the production of electricity resulting in less emissions and pollution and a decreased ecological footprint of cities. ***Health & Well-being:*** Healthier and more attractive lifestyles, better access to living areas, enhance attractiveness of the cities. The design approach of eco-districts, integrating the core elements of sustainability in the development of a specific neighbourhood, it upgrades the living standards of the area through an improvement of infrastructure and public space, finally triggering a change of culture in the citizens. This virtuous effect avoids deprivation of urban areas, and enhances the attractiveness of the city as a whole. From a health perspective, higher or lower indoor & outdoor temperatures, caused by inappropriate heating and cooling of buildings and inadequate design of public space (i.e.: heat-island effect), seriously affect human health and heat-related mortality and morbidity. Energy conservation and renewable energies systems implemented in energy-efficient buildings help to keep indoor temperature at proper levels and protect the health of the tenants, in the same way resilient and climate-oriented public-space design does, both contributing to less premature deaths, increase the life expectancy, decrease the risk of heat related mortality and morbidity and in general reduces the health risk from extreme heat events.

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Concept: Eco-districts / Green neighbourhoods	
	Economy: Job Creation Labour productivity, Proximity economy, Better working conditions. A review of the literature shows that for a similar energy output, solar energy creates 55-80 times as many direct jobs as natural gas, energy conservation measures create 26 times as many direct jobs as natural gas at about one-ninth to one-fifth of the cost. At the same time, for a similar energy output, solar heating systems create 2-8 times more direct jobs than conventional power plants. According to the European Green Deal Strategy 160 000 additional green jobs could be created in the construction sector by 2030. ***Economic risks mitigation:*** Energy security and Safety and Security (Reduced energy poverty, Increased access to clean, affordable, and secure energy): Use of energy conservation and of renewable energies in the development of eco-districts helps to improve energy security and safety while contributing to alleviate energy poverty. Unfortunately, no data is currently available on the impact of efficient energy buildings on energy poverty. However, the development of efficient energy buildings 'brings many positive effects: (i) improving people's living conditions, (ii) decarbonising the energy system, (iii) sustaining recovery and growth. These are the main objectives pursued by the recent Renovation Wave, which as the backbone of the EU Green Deal on energy efficiency in buildings, shows a focused orientation on fighting energy poverty. Among the key actions to be taken in 2021, the EU is committed to "tackling energy poverty and worst-performing buildings: launching the Affordable Housing Initiative piloting 100 renovation districts. Renovation and improvements to the energy performance of buildings would also bring multiple indirect effects, such as (i) improvement of health, due to the reduction of air pollution, and consequent reduction of healthcare costs, and (ii) boost economic activity', Other co-benefits relevant in the deployment of eco-districts are: resource efficiency (waste, water, land-use and even food), greater biodiversity, and social inclusion.
EXTERNAL LINKS	• Eco-districts: development and evaluation. A European case study (Flurin) • Assessing Neighborhood Livability: Evidence from LEED for Neighborhood Development and New Urbanist Communities (Szibbo) • DGNB System for Districts • Leadership in Energy and Environmental Design Neighborshood Development (LEED ND) • Breeam Communities • HQE Aménagement (HQE A) • STAR Communities Rating System
EXAMPLES	Several initiatives have addressed the development of eco-districts/ green neighbourhoods, and an evolution is perceived from earlier to last generation developments. A list of case studies and integrated guidelines for sustainable neighbourhood design is provided here below: • Integrated Guidelines for Sustainable Neighbourhood Design - UN Environment Programme (https://www.neighbourhoodguidelines.org) • Quality Program in Malmö, Sweeden • Hammarby Sjöstad Green Regeneration in Stockholm, Sweeden • Urban Regeneration, Street Patterns and nework of public spaces in King's Cross, London, UK • Promoting Cycling in Copenhagen, Denmark • The Zero-Energy Ecovillage in Bedzed, UK • Ecocity of Trinitat Nova, Barcelona, Spain • Ginko in Bordeaux, France • Docks de Saint Ouen, France • Hiedanranta - Smart & Sustainble City in Tampere, Finland

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Concept: Eco-districts / Green neighbourhoods	
PRE-CONDITIONS & ENABLING CONDITIONS	***Governance, policy, and regulation:*** Adequate framework conditions are key for a suitable deployment of an eco-district. A suitable governance model is key for the potential success of an eco-district, incorporating interests of citizens and the private sector as future users of the eco-district. Policies and city strategies must reinforce eco-distort deployments (i.e.: as elements of an action plan), contributing to the fulfilment of cities' objectives (i.e.: CO2 reduction, well-being). Regulation must be considered in early stages, as well as urban planning limitations. ***Climate and geography***: Eco-districts can be implemented under all climatic conditions. The specific design should follow the main sectoral requirements (energy, mobility, green infrastructures, water & waste management, public lighting, etc.) and should be fitted to the local needs. ***Upstream community work***: Eco-districts that target the already built environment, they require an agreement between inhabitants, owners, real estate companies and other stakeholders. Working with the community prior to interventions is critical, including attending to and understanding the demands of the residents both individually and as a community and being able to convey how the improvements in the renovation of buildings and public space are connected to those demands: Hierarchize the solutions and prioritize them according to their cost and impact. Adapt solutions to the social context and its economic resources. Establish a sequence of possible interventions according to the budget of the tenants/owners who must implement them. Get tangible results in the first actions that allow user loyalty and encourage them to continue with the process. Specify and transmit in a clear and simple way the impact of the proposed solutions in the different areas that affect the citizen: environmental, health, economic, etc. Funding and financing: an appropriate funding and financing scheme is crucial for such a huge investment. So far, this kind of projects are attached to national or regional funds, but they must incorporate citizens and the private sector as part of the scheme.
CONSTRAINTS/ BARRIERS for implementation	**Lack of knowledge on the benefits** and co-benefits of the eco-district approach could reduce the attractiveness of the project for residents and companies. **Lack of skills**: lack of competent experts to carry out **participatory processes** Lack of practice: **community not accustomed to participatory processes** and common decision-making. **Lack of knowledge of funding** options available **Short-term thinking in financial terms** can prevent developers from more suitable approaches thinking in the mid-long term **Land-use regulation** that may hinder alternative/ innovative approaches (i.e.: implementing a district heating network where there is no culture of such approach) Innovation resistance **Lack of insight of future living conditions** of an eco-district (tangible vision)
INSTRUMENTS/ Processes for implementation	***Educational/ Capacity building***: **Trainings**: Training of urban planners, architects, engineers, sociologists (...) on the optimum design and implementation of Eco-districts. Additionally, training processes for residents so that they can understand the advantages and consequences of the required solutions and make decisions based on concrete knowledge. ***Informative/ Awareness raising and Citizen Engagement***: **Workshops**: Organisation of dedicated workshops on the design techniques and the implementation of Eco-districts from a collaborative perspective. **Consultations**: Understand the concerns, needs and resources of residents in order to better address them to get a positive involvement.

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Concept: Eco-districts / Green neighbourhoods	
	Co-design: Collaboratively design the development and work on the needs and resources of residents. **Drop-in sessions**: Use communal spaces for initial contact with residents and raise queries. **Local and permanent technical office**: to set a dialogue with the residents, solve doubts and help with technical answers, etc. **Makerspaces** to prototype tailored solutions. ***Planning***: **Integrated action plans**: this is one of the key instruments to be used when planning eco-districts, braking silos among disciplines for an integrated approach, developing collaborative processes. **Integrated land use planning and urban space management with mobility planning** ***Financial/ Fiscal***: **Grants/subsidies**: Provide reasonable subsidies to investors on energy-efficiency, eco-mobility, and environmentally friendly waste management systems. CO2-based taxation can be considered for energy and mobility purposes. ***Regulatory***: Review of land-use restrictions according to the solutions to be implemented in the district Promote the use of energy conservation and renewable energy systems in buildings from a district perspective Define minimum energy performance standards for existing buildings Lifecycle emissions requirements for construction and renovation projects, products and materials Define specific criteria to favour active mobility in the district (i.e.: bike storage in buildings) **Low-emissions zones** and **Urban vehicle access regulations** can be considered to reduce fossil-fuels based mobility in the district. Define specific criteria on waste management procedures to maximise circularity and reuse. ***Technical***: **Provision of energy efficient products and services**: Set appropriate municipal targets and standards on the implementation of energy conservation and renewable energy systems in local building stock **One-stop shops** as a helpful way to combine retrofitting techniques **Circular economy design principles** must be included in early stages to increase the durability, reparability, upgradability and reusability of materials.
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	The development of eco-districts does not conflict with any of the DNSH principles (EU 2020/852). However, eco-districts usually require higher investments than conventional neighbourhoods, which can cause the developers to pass on the higher costs to their customers. This must be carefully supervised by local authorities in order to avoid gentrification processes.
IMPACTS (Indicators & DNSH)	Emissions, energy consumption and associated costs: combining energy efficiency actions with the deployment of renewables will both reduce the energy consumption, the GHG emissions, and the operational costs of a district. The implementation of eco-districts instead of business-as-usual developments presents several energy and emissions related benefits: • Decreases the absolute energy consumption during the whole year at the city scale (kWh/m2/y). • Decreases the release of harmful pollutants from the heating and cooling systems of the buildings. • Decreases the peak electricity demand during the year and the need to build additional power plants.

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Concept: Eco-districts / Green neighbourhoods	
	• Decreases the cost of electricity as the absolute peak demand is seriously reduced. • Decreases the total annual operational costs per unit of energy output (EUR/MWh or EUR/MJ) • Decreases the release of anthropogenic heat and reduces the magnitude of local overheating. • Decreases the passenger kilometre energy intensity (MJ/pkm) **Examples of proposed indicators to measure the impacts of this solution if applied in a city:** Energy savings compared to reference buildings (% kWh/m2/y). Calculate the energy consumption before the implementation of the global energy system, A, in kWh/m2/y and the corresponding energy consumption when the full energy system is implemented, B. Then calculate the Impact Indicator as E=A-B GHG emissions avoidance (e.g., by removing the need for energy consumption) in %CO2e. Calculate emissions corresponding to the energy consumption A and B, as above, then calculate the difference.

4.1.4 Concept: Smart Grid

- Authors: **VTT**
- Knowledge Repository link: **https://netzerocities.app/resource-3268**

Concept: Smart Grid
Smart grid is the concept that describes the evolution of power systems to integrate and utilise techniques to adjust the flow of power to optimise the match between electricity supply and demand. The term "smart grids" is used to define the integration of new technologies and methods, often data-driven, in existing power system infrastructure. Sensing infrastructure, smart metering, information and communication technologies (ICT), such as sensing devices and smart metering; techniques such as novel optimisation methods and control architecture for managing power flow, energy management systems, load aggregation techniques; and new business model and end-user participation schemes - all these technical concepts fall within the field of Smart Grids. Therefore, such a broad field offers many different opportunities and solutions for various challenges with electricity generation, transmission, distribution, and consumption. According to (1), such challenges can be classified in terms of their domains - the actors involved and main stakeholders, in zones, and their interoperability layers with several cross-cutting issues.

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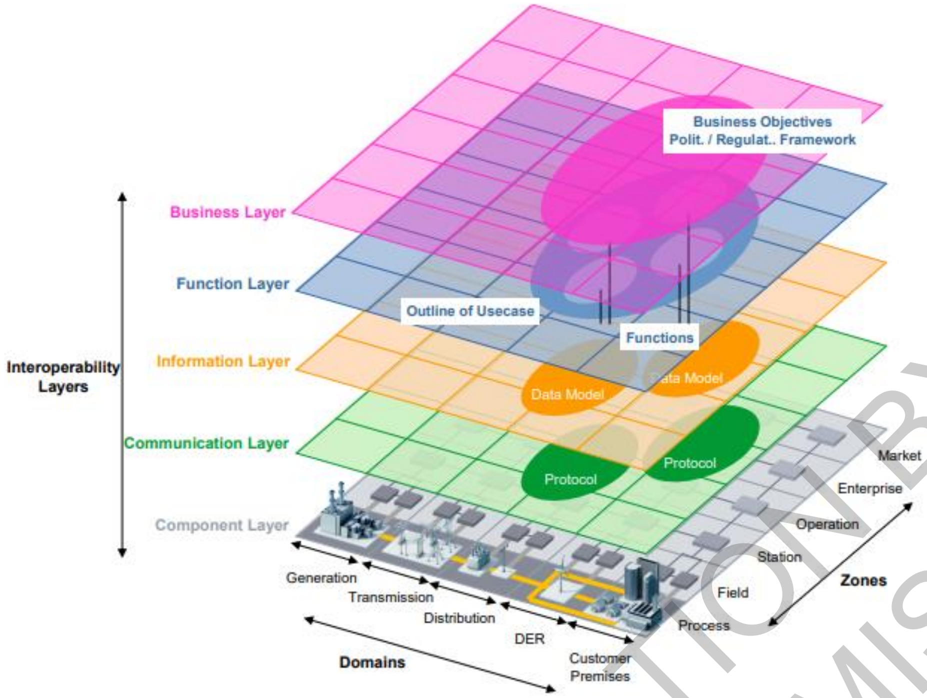
Concept: Smart Grid



The SGAM framework and the different domains, zones, and layers that compose smart grid solutions (1)

In the context of smart city solutions, a smart power grid is mostly related to the:

1. efficient integration of clean and renewable energy generation and energy storage systems;
2. efficient consumption of electricity;
3. reliable availability of electricity supply and grid operations;
4. effective business models that incentivise active participation of new market players, such as aggregators, energy companies, or citizens in demand response and flexibility provision;
5. safe, reliable, efficient, and secure management of data related to critical infrastructure (2, 3, 4).

The European Union has invested heavily on the research and development of smart grid technologies, with approximately €1 billion invested in research in smart grids and energy technologies in the Horizon 2020 and Horizon Europe programmes (5). Smart grid solutions are key enablers for the transformation of the European energy system towards decarbonisation and resilience, and thus are listed as one of the priorities of the European Green Deal (6).

The plans of the REPowerEU actions (7) strive to bring the total renewable energy generation capacity installed in europe to 1236 GW by 2030, a measure that is only feasible with the implementation of distributed generation actions supported by smart grid technologies. Specifically, the EU Solar Energy Strategy (8) aims at increasing the installed capacity of solar photovoltaic in 2030 to twice the levels found in 2023. Such rapid increase in the integration of distributed generation is bound to cause grid congestion and power quality issues, mitigated by smart grid technologies.

An important sub-field of smart grids is on the design and operation of microgrids and energy communities, a particularly relevant concept in the context of smart cities and buildings (9). Microgrids are local electricity grids that can operate either independently (off-grid, or islanded mode) or connected to larger smart grids. Microgrids can range from district-level to individual building-level (nano-grids). The concept of microgrids support the implementation of wider smart grid concepts in smaller locations by reducing the scope and costs of implementation projects (10).

The main purpose of this document is to provide knowledge, information and a reference for the decision makers, city authorities, utilities, planners and building professionals to consider the suitable

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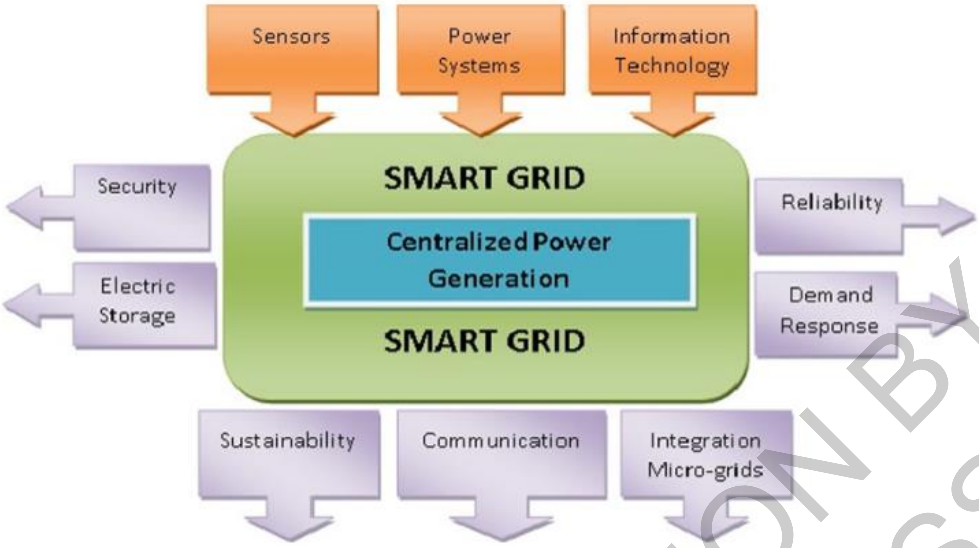
Concept: Smart Grid	
use cases and the potential implementation of smart grid solutions to support smart buildings and cities.  *Overview of the Smart Grid Architecture (11)*	
CO-BENEFITS	***Economy:*** <u>Job Creation Labour productivity, Better working conditions.</u> Since the concept of smart grids is so broad, it is difficult to measure specifically how many jobs are created from related projects in accurate detail. However, with the development of smart grid services, there is a clear need for engineering service provision and for power system operation services. These two sectors compose the majority of the job creation opportunities with smart grid projects. Indirectly, there is a significant amount of jobs created with the implementation of renewable energy generation and energy storage installation projects (12, 13) ***Economic risks mitigation****:* <u>Energy security and Safety and Security (Reduced energy poverty, Increased access to clean, affordable, and secure energy):</u> Smart grid solutions support the integration of clean and renewable energy generation resources in power systems, both in centralised power plants and distributed generation. Energy storage solutions are also further enabled by the concept of smart grids. The efficient coordination between electricity availability and demand in the power system supports the increase in grid reliability, reducing the risks of outages and loss of capacity. Smart grid solutions such as utilising power quality measurement data from power system infrastructure to forecast grid faults and perform predictive equipment maintenance has the potential to reduce the expected energy not served (EENS) values, thus reducing the amount of economic damages incurred to end-users (calculated with the Value of Lost Load, VLL). ***Health****:* Access to clean and reliable electricity is a factor that contributes to higher quality of life and health standards (14, 15). Smart grid solutions can support the integration of clean energy resources and energy storage, increasing grid reliability and decreasing the interruption of supply periods. ***Environment:*** **<u>Environmental risks mitigation: Reduced ecological footprint</u>**: The more effective and efficient integration of renewable energy generation technology, energy storage, and demand response results in decreased emissions and a more efficient energy usage, resulting in fewer environmental impacts and a reduced

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Concept: Smart Grid	
	ecological footprint from the generation, transmission, distribution, and use of electricity. **Climate resilience: climate adaptation**: Reduced vulnerability to natural and climate hazards, heat waves and extreme climatic events.
KEYWORDS	Smart grid, demand response, flexibility
EXTERNAL LINKS	***References:*** 1. Smart Grid Coordination Group, Smart Grid Reference Architecture, CEN-CENELEC-ETSI, Tech. Rep., 2012 2. Ken Geisler, The Relationship Between Smart Grids and Smart Cities, IEEE Smart Grids Newsletter, 2013, https://smartgrid.ieee.org/resources?cafid=0&id=223 3. Gharavi, Hamid, and Reza Ghafurian, eds. Smart grid: The electric energy system of the future. Vol. 99. Piscataway, NJ, USA: IEEE, 2011. 4. Sunil Luthra, Sanjay Kumar, Ravinder Kharb, Md. Fahim Ansari, S.L. Shimmi, Adoption of smart grid technologies: An analysis of interactions among barriers, Renewable and Sustainable Energy Reviews, Volume 33, 2014, Pages 554-565, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2014.02.030. 5. EU programmes to support the digital and green transformation of the energy system, 2023, https://digital-strategy.ec.europa.eu/en/policies/eu-programmes-digitalisation-energy 6. A European Green Deal, 2023, https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en 7. REPowerEU: affordable, secure and sustainable energy for Europe, 2023, https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/repowereu-affordable-secure-and-sustainable-energy-europe_en 8. EU Solar Energy Strategy, 2022, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A221%3AFIN&qid=1653034500503' 9. C.F. Calvillo, A. Sánchez-Miralles, J. Villar, Energy management and planning in smart cities, Renewable and Sustainable Energy Reviews, Volume 55, 2016, Pages 273-287, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2015.10.133. 10. Sami, M.S.; Abrar, M.; Akram, R.; Hussain, M.M.; Nazir, M.H.; Khan, M.S.; Raza, S. Energy Management of Microgrids for Smart Cities: A Review. Energies 2021, 14, 5976. https://doi.org/10.3390/en14185976 11. Osama Majeed Butt, Muhammad Zulqarnain, Tallal Majeed Butt, Recent advancement in smart grid technology: Future prospects in the electrical power network, Ain Shams Engineering Journal, Volume 12, Issue 1, 2021, Pages 687-695, ISSN 2090-4479, https://doi.org/10.1016/j.asej.2020.05.004. 12. Tatyana Bulavskaya, Frédéric Reynès, Job creation and economic impact of renewable energy in the Netherlands, Renewable Energy, Volume 119, 2018, Pages 528-538, ISSN 0960-1481, https://doi.org/10.1016/j.renene.2017.09.039. 13. G.J. Dalton, T. Lewis, Metrics for measuring job creation by renewable energy technologies, using Ireland as a case study, Renewable and Sustainable Energy Reviews, Volume 15, Issue 4, 2011, Pages 2123-2133, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2011.01.015. 14. Stephen Tully, The Human Right to Access Electricity, The Electricity Journal, Volume 19, Issue 3, 2006, Pages 30-39, ISSN 1040-6190, https://doi.org/10.1016/j.tej.2006.02.003. 15. Reza Nadimi, Koji Tokimatsu, Modeling of quality of life in terms of energy and electricity consumption, Applied Energy, Volume 212, 2018, Pages 1282-1294, ISSN 0306-2619, https://doi.org/10.1016/j.apenergy.2018.01.006. 16. EU initiatives for smart energy systems, Accessed 2023, https://energy.ec.europa.eu/topics/research-and-technology/eu-initiatives-smart-energy-systems_en 17. Grid Resilience and Innovation Partnerships Program (GRIP), Accessed 2023, https://www.energy.gov/gdo/grid-resilience-and-innovation-partnerships-grip-program 18. Smart Metering deployment in the European Union, Accessed 2023, https://ses.jrc.ec.europa.eu/smart-metering-deployment-european-union
EXAMPLES	There are many smart grids projects implemented worldwide, with varying topics and use cases (i)-(v). Specific use cases are demonstrated to be very cost-effective and to increase grid reliability. Grid investments are still needed to support the development of digitalisation solutions and the connection of renewable energy generation. The rollout of smart metering in the European Union can be considered as one of the largest smart grid-related projects in the world, with a massive investment in grid infrastructure at the consumer end-point. (18) ***SINCROGRID*** is one of the most relevant smart grid projects in Eastern Europe, with investments in grid infrastructure and grid intelligence in Slovenia and Croatia. The project has focused on use cases related to the integration of energy storage systems, power quality compensation, and grid management systems for the monitoring and control of power flow between regions.

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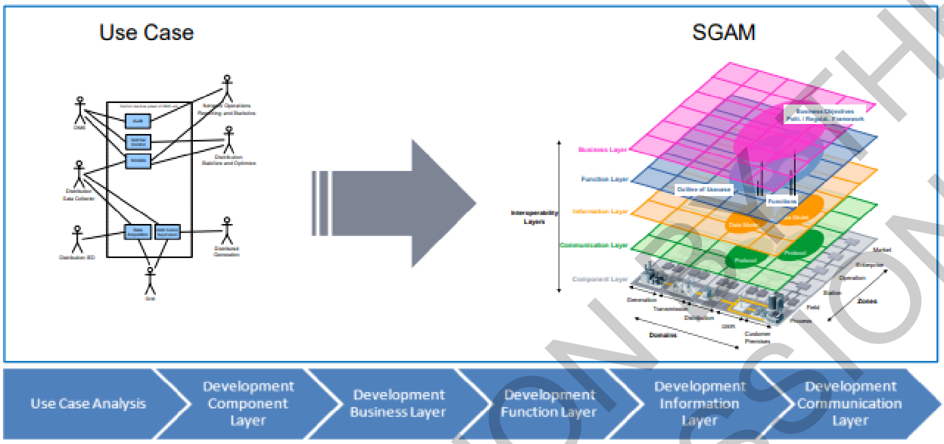
Concept: Smart Grid

[DanubeInGrid](#) is a project between Slovakia and Hungary focusing on grid investments to support the integration of renewable energy resources and optimal coordination between market regions. The project also focused on the interaction between transmission and distribution system level and on cyber security applications in smart grids.



From use case analysis to the development of smart grid solutions utilising the SGAM framework

Concept: Smart Grid

PRE-CONDITIONS & ENABLING CONDITIONS

***Preconditions**:*
Smart grid solutions are suitable for all climactic zones of Europe, but when considering how smart grids can serve as enablers for flexible energy resources, areas with higher renewable energy potential tend to benefit more from these applications. Moreover, regions that have been impacted by climatic events such as storms and heat waves may benefit further from projects that increase the grid flexibility and reliability.
The specific design should follow the local grid requirements and should be fitted to the local needs. Design and planning teams must identify the most appropriate use cases and necessary smart grids solutions to maximise the cost-benefit of smart grid solutions.
Existing grid equipment and communication infrastructure must be analysed and considered when designing the implementation of smart grid use cases. The capabilities of existing infrastructure need to be taken into consideration when identifying potential investments and retrofits. Considerations on e.g., power line and substation transformer capacities must be taken into account, as well as the pre-existence of data collection devices (e.g. smart meters at consumer sites).

Specific Preconditions:
Climate and geography: Smart grid solutions can be implemented under all climatic conditions, with different use cases being suitable for different weather conditions. For instance, grid fault detection caused by icing on power lines is a use case that is only suitable in low-temperature locations.
Policy and regulatory/legal framework: Existing policy framework supports the large-scale integration of renewable and distributed energy resources, with focus on e.g. electric vehicles and solar power. These incentives will lead to a strong need in modernising the electricity grid through the implementation of smart grid solutions in Europe. City authorities and utilities should consider the specific challenges that arise in their own specific conditions, identifying issues such as grid congestion, power quality issues, or reliability issues.

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Concept: Smart Grid	
	Funding and financing: Financing for smart grid projects depends on their scope and solutions proposed. For smaller-scale projects with use cases reaching higher technology readiness levels, financing may typically come from own investments from utilities and grid operators, which are in turn shared with customers through grid tariffs. Nevertheless, there are still many opportunities for public funding and grants for smart grid-related projects. Europe (16) and the United States (17) for example have declared investment programmes aimed at revitalising and modernising their grid infrastructure through smart grid applications. Cities and regions can partner with utilities and technology providers for the design and demonstration of smart grid solutions. Co-financing alternatives are available from several energy-related European initiatives.
CONSTRAINTS/ BARRIERS for implementation	The high cost of implementing smart grid solutions is a major barrier for the wider integration of smart electrical networks (4). Given that power systems are considered critical infrastructure, the cost-benefit ratio for the implementation of new methods and approaches needs to be very advantageous to utilities and grid operators. With the rising penetration of renewable energies, the deployment of solutions to effectively plan and manage electricity systems becomes more crucial, and thus the benefit of smart grids becomes more prevalent. Moreover, aspects such as electricity pricing and capacity availability also play an important role in cost-benefit analysis for smart grid projects. There is a significant range of technical and technological smart grid solutions that are yet to be fully realised, such as (i) fast, secure, and reliable data communications from sensing infrastructure via wired or wireless communications; (ii) energy management systems at distribution system level; (iii) grid congestion management systems; (iv) fast techniques for data processing at the edge; (v) predictive maintenance of grid infrastructure, fault detection and fault localisation; (vi) effective demand response participation incentives for end-users; among others. Although a significant amount of research and development has been placed into different fields of smart grids, and there are already plenty of implementations worldwide of systems that can be classified as "smart grids", there are still many development aspects that need to be considered. A significant barrier for the implementation of smart grid solutions lies in ensuring a safe and reliable data communication between the sensing infrastructure, including smart meters and grid sensors, and centralised/edge control systems. Data communication reliability and data security are critical aspects in the operation of power system infrastructure.

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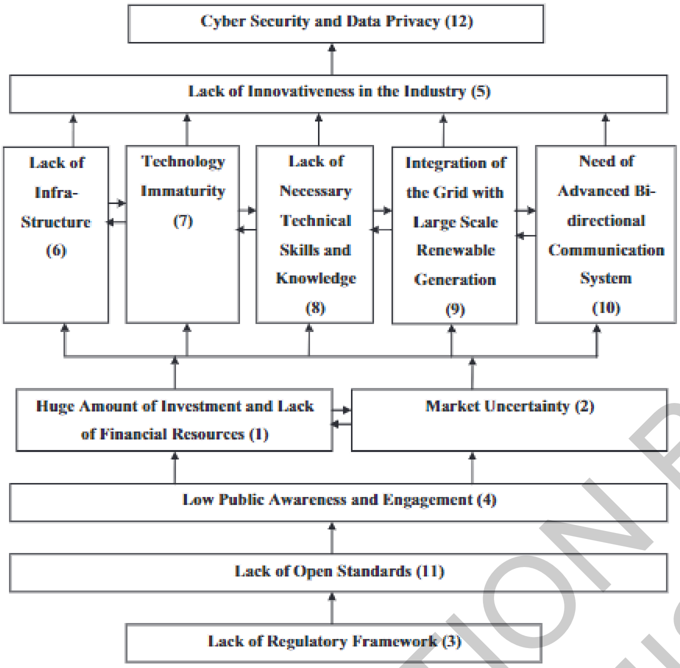
Concept: Smart Grid



Hierarchical model for the barriers to adoption of smart grid technologies (4).

INSTRUMENTS/ Processes for implementation

Educational/ Capacity building

Trainings: Training of policy makers, technology developers (software, hardware), energy engineers, power system engineers, electrical technicians, on the optimum design and implementation of different smart grid solutions.

Informative/ Awareness raising

Workshops and Awareness Campaigns: Organised discussions with electrical utilities and energy companies to identify opportunities and bring awareness to the possibility of implementing smart grid solutions.

Planning

Integrated action plans: Implementation of an integrated action plan to increase the energy conservation and the use of renewable energies in the built environment. Promote and plan the use of electricity and thermal energy storage in buildings.

Financial/ Fiscal

Grants/subsidies: Provide reasonable subsidies to investors on positive energy buildings and CO2-based taxation of energy carriers for heating. Provide financial support to supplement general pricing and regulatory policies. Provide subsidies for the implementation of efficient electricity and thermal storage in buildings.

Regulatory

Promote the use of energy efficiency measures in buildings, and renewable energy generation integration to buildings and as stand-alone power plants.

Define minimum energy efficiency standards for existing buildings.

Set maximum values for the loss of energy in transmission and distribution processes. Define maximum electricity distribution interruption durations that are stricter than the current standards to promote higher reliability in the power system. Efficient pricing and regulatory instruments must be defined and implemented now to limit the electricity costs for society.

Promote the implementation of electricity storage systems in buildings and sector integration (with thermal, transportation) solutions for power-to-X and X-to-power solutions.

Technical

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Concept: Smart Grid	
	Provision of energy efficient products and services: Set appropriate standards on the implementation of energy efficiency, power quality monitoring, and renewable energy/energy storage systems in local grids. Implementation of smart metering infrastructure.
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	Smart grid solutions, such as grid power quality monitoring and energy management systems, tend to require extensive sensing infrastructure. Energy management systems and grid congestion management systems also require reliable and constant communications between the monitoring and control systems, which can be costly. Utilities typically will revert these costs to end-users through distribution pricing. Furthermore, issues related to cyber-security are considerable, given that the operation of critical infrastructure may become exposed if appropriate cyber-security measures are not set in place.
IMPACTS (Indicators & DNSH)	***Energy Impact:*** The energy benefits of smart grid solutions are heavily dependent on the use case, scope of the project, and operational conditions. The impacts are typically associated to increased energy efficiency and reduction of grid losses; to the integration of more sustainable and green energy generation resources; or to the increase in grid reliability and availability of electricity access. Demand response and peak shaving applications can greatly impact the grid operations and thus their reliability and resilience. Smart grid projects also have the potential to impact energy use and distribution through the implementation of projects focusing on energy management systems for the coordination between availability of generation capacity and the electricity consumption at the end-user side. ***Provide Comfort:*** Smart grid solutions provide comfort to end-users by ensuring a more reliable and sustainable supply of electricity. Advanced energy management systems and aggregation methods can also provide comfort to users through the automated operation of consumer devices to maximise their flexibility potential while ensuring no-harm-done and no loss of comfort to end-users. Examples of proposed indicators to measure the impacts of this solution: • Electricity pricing (€/MWh or €/kWh) can be used as a measure to identify the impacts of smart grid solutions; initial pricing tends to be higher to account for potential grid investments and to supplement the investment costs partaken by utilities and grid operators, but with the integration of renewable energy and energy storage resources, electricity pricing tends to drop in smart grid projects. • System average interruption duration index (SAIDI), system average interruption frequency index (SAIFI), customer average interruption duration index (CAIDI) can be used to measure the increase in grid reliability and electricity supply access
Additional information from CASE STUDIES	The active involvement of citizens in smart grid projects typically is related to the participation in demand response initiatives. Robust value-creation and value-sharing methods, including the economic and social value of demand response, must be in place to incentivise the participation of end-users. Critical ICT infrastructure is needed as a backbone for smart grid deployment. Data platforms, management systems, communication standards and cyber security procedures must be in place to ensure the necessary reliability of data communications and control systems in smart electricity networks. Concerns about data ownership, specifically when considering electricity consumption data from end-users, is due to become a key aspect in demand response and load flexibility actions. Several stakeholders must be involved in the deployment of smart grid solutions. Grid operator and utilities are the main drivers of such efforts, but local

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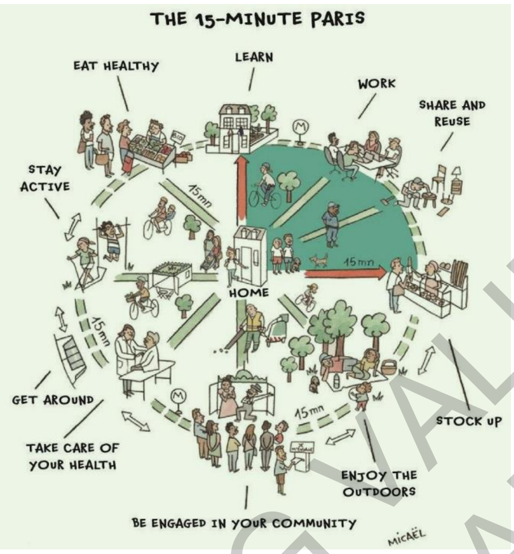
Concept: Smart Grid	
	governments, municipalities, citizen representatives, and technology providers are key players in smart grid projects and their involvement is critical.

4.1.5 Concept: 15-minute city

- Authors: **Rupprecht, EIT-UM**
- Knowledge Repository link: https://netzerocities.app/resource-3278

Concept: 15-minute city

The concept of the **15-minute city** is one of the most prominent attempts to avoid or shorten trips in people's everyday lives. This can be achieved **if essential services** (e.g. shops, pharmacies, schools, work places, hospitals, leisure destinations etc.) **are physically close to people's residential bases**. The 15-minute city concept is thus tightly linked to spatial planning strategies and places strong emphasis on neighbourhood-based planning.



The 15-minute city can be a **major contribution to carbon reduction strategies** because fewer and/or shorter trips obviously mean fewer emissions but also because shorter trips are easier to cover on bike or by foot. A 15-minute city is also beneficial in terms of convenience, accessibility, safety and public health. Shorter trips also improve social equity because people who do not want to or are not able to own and/or drive a car can still reach their destinations.

Although related spatial planning ideas have been around for centuries, the "15-minute city" idea as a slogan has gained enormous prominence within the last few years. This is due to a large extent to the official endorsement and practical pursuit of the 15-minute city concept in Paris. It also resonates with the growing awareness that technical fixes alone (e.g. electromobility) will not be enough to achieve climate neutrality.

Within the widely established **A-S-I pyramid**, the 15-minute city concept falls firmly within the first, most effective and most important category to "A"void unnecessary trips; but it also contributes to a "S"hift from private motorized vehicles to more sustainable modes of transport (public transport, cycling and walking). It does not - and deliberately so - contribute to the attempt to "I"mprove mobility through technical fixes (e.g. alternative propulsion, smart traffic management etc.) and thus to "Improvements" to reduce the harmful effects of private motorized mobility.

EIT Urban Mobility (2022) mentions the following eight planning principles for a 15-minute city: Proximity to essential services | Proximity to public transport | Density | Mixed land use | Walkable and cyclable streets | Liveable public spaces and placemaking | Inclusiveness | Ubiquity.

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Concept: 15-minute city	
CO-BENEFITS	Enhance stability of the urban infrastructure; Reduce GHG emissions; Reduce energy needs; Boost local business (km 0); Proximity economy; Increase employment rate and Jobs; Decrease future maintenance costs; Social cohesion (gender, minority groups); Social capacity building; Enhancing citizen participation, connectivity, and community; Raised awareness/behavioural change; Improved access to job opportunities; Promote the materials cycle; Sustainable and resilient food systems; Improve land use management; Improve air quality; Reduce noise pollution; Reduction of road danger; Enhance attractiveness of the cities; Healthier and more attractive lifestyles; Better physical activity of individuals; Better access to living areas for all; Reduce ecological footprint.
KEYWORDS	**Replication activities**: Learning from other cities that have implemented similar spatial planning approaches. Together with the measures themselves, issues around governance, financing, user needs and public acceptance, compliance and complementary measures are important to the successful implementation of the 15-minute city concept. **Stakeholders' engagement**: As the 15-minute city concept stimulates, requires and facilitates a change of people's unquestioned routines, it is important to have stakeholder understanding of the problems to be solved and buy-in for the proposed measures. This requires an ongoing engagement process with a wide range of stakeholders.
EXTERNAL LINKS	• https://www.eiturbanmobility.eu/wp-content/uploads/2022/11/EIT-UrbanMobilityNext9_15-min-City_144dpi.pdf • https://www.nature.com/articles/s41599-022-01145-0 • https://www.mdpi.com/2624-6511/4/1/6 • https://www.sciencedirect.com/science/article/pii/S0264275122005406 • https://netzerocities.app/resource-1688
EXAMPLES	• Dublin 15-min city: Dublin: The 15 Minute City - Council.ie • Portland 20-minute city: Portland's 20-Minute Neighborhoods after Ten Years: How a Planning Initiative Impacted Accessibility (washington.edu) • Edinburgh 20-minute city: 20-minute neighbourhoods – The City of Edinburgh Council

Concept: 15-minute city	
PRE-CONDITIONS & ENABLING CONDITIONS	***Generally speaking:*** The full grasp of factors that can foster the move towards a 15-minute city requires a corresponding understanding of related barriers in the sense that the absence of the latter can be interpreted as a conducive factors. It is therefore recommended to also read the section about obstacles. ***Political:*** Helpful – if not a precondition – for the 15 minute city idea to flourish is a critical attitude towards „technical fixes“, that is, the assumption that technological advances can solve all transport-related problems. This goes hand in hand with a realisation that transport-induced challenges are much more than exhaust-point emissions of carbon. ***Economic:*** A courageous implementation of the 15-minute city concept will require some infrastructural adjustments to facilitate safe and convenient trips, primarily by walking or cycling, within the 15-minute perimeter of people's homes. This comes at a cost. However, these costs (investment and long-term maintenance) are far lower than investments in conventional road infrastructures. ***Social:***

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Concept: 15-minute city	
	A 15-minute city or neighbourhood is far more conducive to serendipitous social interactions and is therefore likely to be particularly welcome in areas with an existing high appreciation for friendly social encounters. This is by no means a precondition though, but can be a beneficial result of spatial and infrastructural features, which make it easy and likely to interact with other people. ***Technical:*** Implementing the 15-minute city concept is not dependent on special sophisticated technology. It can be fostered though through digitally assisted tools like MaaS applications, car- and bike-sharing platforms, ISA (intelligent speed assistance), various approaches to enforce certain regulations (e.g. UVAR, urban vehicle access regulations) etc. ***Legal:*** Most elements of a 15-minute city make it easy, safe and convenient to meet people's daily needs on foot, by bicycle or by public transport. To steepen the relative advantage of these modes of transport vis-á-vis the privately-owned car it can be beneficial to reduce the attractiveness of the latter through various car-discouraging measures. Some of them are dependent on (national) legal settings, such as camera-based techniques to enforce access regulations.
CONSTRAINTS/ BARRIERS for implementation	***Political:*** Underlying the 15-minute city concept is a quite comprehensive understanding of challenges as a complex conglomerate of issues around spatial planning, transportation, urban design, politics etc. It can therefore be challenging to promote and pursue this approach if the political discourse tends to focus narrowly on the expectation that isolated "fixes" can solve complex problems. Similarly, political fragmentation can be a stumbling block when cities are composed of multiple political jurisdictions, each with its own set of priorities and interests. This can make it difficult to coordinate efforts to create a 15-minute city across the entire urban area. Also, a lack of political will and ambition can hinder the path towards a 15-minute city because it requires significant investment of time and resources, as well as a willingness to challenge the status quo of urban planning. ***Economic:*** Budget constraints can be an obstacle on the way to a 15-minute city because it requires significant investments in infrastructure, public transportation and public spaces. This can be difficult in times of economic austerity. Also, resistance from developers can be problematic because they not always embrace the idea to prioritise walkability and accessibility over other factors like maximizing profit or accommodating car traffic. Very importantly, the benefits of a 15-minute city are unlikely to manifest immediately in monetary terms. They tend to show in the longer-term through the retention of jobs, stabilisation of decentral economic activities, avoidance of expenditures etc. Conventional cost-benefit analyses can therefore be problematic. ***Social:*** Social obstacles on the way towards the 15-minute city can emerge, at least initially, if people feel insecure about the impacts of the planned changes on their daily lives and routines. Also, retailers might be concerned that they might lose parts of their customer base if their stores cannot be accessed by private car any longer. In some cases, even conspiracy theories developed around the 15-minute city concept as an alleged way of the government to corral people into their neighbourhood and to control their every move in the sense of pervasive surveillance. ***Technical:*** The 15-minute city concept does not rely on specific critical technical or technological components. However, the 15-minute city only works if – by definition – services and amenities are safely and conveniently accessible within short

Concept: 15-minute city	
	distances. This can be seen as a technical challenge because it requires creating new public spaces like parks and plazas, as well as investing in public facilities such as libraries, hospitals, community centres and schools. Furthermore, the 15-minute city rests on the availability of transportation infrastructure that supports walking, biking, and public transit. This requires rethinking the way streets, sidewalks and the public realm in general are designed. Thirdly: In order to design effective 15-minute cities, planners and policymakers need access to accurate and up-to-date data on population demographics, land use patterns, transportation patterns and other factors. This requires large amounts of data and their analysis, which in turn necessitates funding, competences and new partnerships between government agencies, private companies and citizens. ***Legal:*** Some spatial planning and zoning ordinances at the local and regional level are ill-compatible with the 15-minute concept if they stipulate a strict separation of spatial uses like retail areas, recreational destinations, residential quarters etc. Also, minimum parking requirements are a form of legal obstacle as are historic preservation rules if they prevent multifunctional uses of buildings. In some cases, the right to appeal can be challenging if it is used by NIMBY groups to prevent (infra-)structural changes in their neighbourhood.
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	While the concept of a 15-minute city has many potential benefits, there are also some potential negative consequences that should be considered: Gentrification is one of them because the increased demand for housing in highly accessibly and therefore attractive areas with low transport-induced problems (e.g. noise, risk of crashes, air quality) could drive up real estate prices and push out long-time residents. The move to a 15-minute city could also result in limited job opportunities for people, whose skills and qualifications are not sought after in their neighbourhood. This depends of course on the mix of businesses and services in a given area. Also, the potentially high cost of creating a 15-minute city should be mentioned, particularly if significant investment in new infrastructure and public facilities is required. This could lead to higher taxes for residents.
IMPACTS (Indicators & DNSH)	Measuring the success of a 15-minute city can be challenging, as it involves a wide range of factors, including social, economic, environmental, and health outcomes. Here are some possible success indicators: ***Walkability:*** One important measure of success for a 15-minute city is the degree to which it is walkable. This can be measured using a variety of parameters, such as the length of pedestrian-friendly streets, the availability of sidewalks and crosswalks, and the overall safety of walking and biking in the area. ***Accessibility:*** Another key measure of success for a 15-minute city is the degree to which residents have access to essential goods and services within a short distance of their homes. This could be measured by looking at the number and variety of businesses and services in the area, as well as the affordability and accessibility of public transportation. ***Social equity:*** The success of a 15-minute city could also be measured in terms of social equity, such as whether the benefits of the initiative are shared equitably across different socioeconomic groups. This could be measured by looking at factors such as income levels, race and ethnicity and access to affordable housing and transportation.

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Concept: 15-minute city	
	Environmental sustainability: Another important measure of success for a 15-minute city is its impact on the environment. This could be measured using a variety of indicators, such as the reduction in greenhouse gas emissions and air pollutant emissions, the amount of green space and public parks in the area and the degree to which the area is designed to be energy-efficient and sustainable. ***Economic vitality:*** Finally, the success of a 15-minute city could be measured in terms of its impact on the local economy. This could be measured by looking at factors such as job retention and creation, business development and the overall vibrancy of the local economy. It is advisable to develop indicators that are easy to understand and easy to communicate. An example of such a directly graspable indicator would be: "The percentage of parents who let their nine-year-old child go to primary school without supervision."

4.1.6 Concept: Industrial symbiosis

- Authors: **TNO**
- Knowledge Repository link: **https://netzerocities.app/resource-3288**

Concept: Industrial symbiosis
Industrial Symbiosis (IS) is an innovative approach that brings together companies from different sectors to promote the valorisation of waste, improvement of resource efficiency and reduction of environmental impact.(Optimising Environmental Performance of Symbiotic Networks Using Semantics - ScienceDirect) Industrial Symbiosis involves an exchange of products, by-products and/or waste between different industries. Industrial processes use resources such as raw material and energy to produce a specific product. These products can be used by near-by industries as their raw material. In addition, by-products or waste generated by the process lines can also be used as raw material or supplementary resources for other industries. In an optimum industrial symbiosis, the input-output relationship must match, this results in zero or near zero waste generation of all industrial processes involved.

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Concept: Industrial symbiosis	

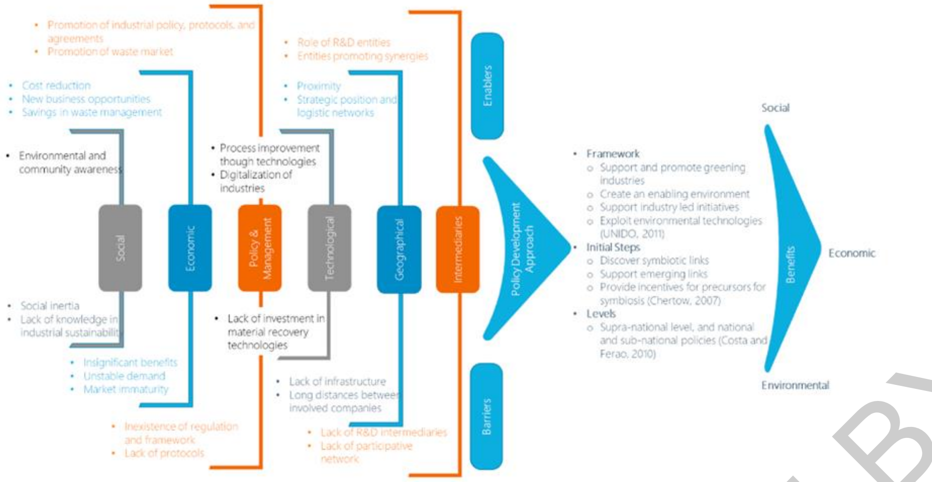

Fig. 16. Potential factors for implementing IS in KSA (Costa and Ferrão, 2010; UNIDO, 2011).

Roadmap for Industrial Symbiosis implementation.

CO-BENEFITS	Industrial symbiosis can offer many environmental benefits, in terms of waste efficiency, as it can offer **better waste management** and **promote material cycle.** It can further help in **reduction of GHG emissions**, while also creating **economic value** from waste material.
EXTERNAL LINKS	• Industrial_Symbiosis (europa.eu)

Concept: Industrial symbiosis	
PRE-CONDITIONS & ENABLING CONDITIONS	In terms of energy there are two possible exchanging resources, power and heat & cooling. Power generated by industries from CHP, renewable systems, etc. which is not consumed by their own processes can be redirected to other industries. In the same way waste heat (high grade) coming from industrial processes can be utilized by other nearby industrial processes and/or by district heating networks. The same could happen when cooling is the unwanted (waste) product, cooling networks could provide cooling capacity to other industries in need. Therefore, the main criteria for a successful industrial symbiosis are: • The raw material, by-product, product or waste of one industry must be a resource for another one. • The amount of the shared resource must cover a large part of the produced material/energy within the partnership. • The exchange must be economically viable for all involved parts.
CONSTRAINTS/ BARRIERS for implementation	In most cases industries must be located geographically as closest as possible to reduce transport costs, losses, etc. Industries have to redesign their supply chains, and to provide guarantees to the other industries. The cost of implementing different technologies for waste heat recovery, heat transfer, power supply, etc can be excessive in some cases. Shared resources must comply with other industries' regulations, standardization and other technical requirements. Information about the resources, process lines or waste product specs could bring confidentiality issues (industries are not willing to share details of their production lines).

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Concept: Industrial symbiosis	
INSTRUMENTS/ Processes for implementation	• Decarbonisation Plans for Industry: https://netzerocities.app/resource-1718 • Solar Thermal in industries: https://netzerocities.app/resource-1438 • Geothermal heat source solution in industries: https://netzerocities.app/resource-1448 • Waste heat recovery in district heating networks: • https://netzerocities.app/resource-858
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	Industries using perhaps the waste of other industrial processes could create dependence. This could cause issues when industries have drops or rises in production capacity. In partnerships with long term contracts with fixed prices, drop of power/energy costs from the grid can have a huge economic impact on the final product cost.
IMPACTS (Indicators & DNSH)	Emissions, costs
Additional information from CASE STUDIES	Check case studies in: https://doi.org/10.1016/j.jclepro.2022.135536

4.1.7 Concept: Water-Energy-Food-Ecosystem (WEFE) Nexus approach

- Authors: **CARTIF**
- Knowledge Repository link: **https://netzerocities.app/resource-3298**

Concept: Water-Energy-Food-Ecosystem (WEFE) Nexus approach
Current global developments put increasing economic and social pressures on urban systems. While current risks in key sectors such as water (water stress, scarcity, floods), ecosystems (soil, land, biodiversity, etc.) or food (decrease on production, irrigation, etc.) are clearly identified, existing solutions tend to tackle them individually with scarce considerations of intersectoral impacts (e.g. the use of water or energy in the food, or the use of water for energy production and how that can impact food) when in fact connections and synergies among the sectors exist. The **Nexus approach is a holistic concept and methodology that highlights and analyses the interdependencies of water, energy, food and natural resources (soil, land).** The Nexus approach and especially with regards to Water, Energy, Food and Ecosystem (WEFE) sectors, is receiving increasing attention due to its potential to provide integrated cross-sectorial assessments to face multi-agent and multi-scale conflicts, [1] hence **contributing to prioritize security in all essential sectors and to achieve the Sustainable Development Goals** (SDGs).[2] Despite the significant efforts made on a theoretical dimension of the nexus concept, actual implementations are still rare, especially at local or micro levels. The ability to confront these challenges significantly depends on the **resilience of an urban area**, which is to a large degree managed by institutions with the objective of protecting social cohesion and minimizing ecological pressure. Urbanization and climate change, however, strain social cohesion by exacerbating social vulnerabilities and disproportionately affecting those already marginalized. Justice and equity are thus essential preconditions for the development of resilient urban concepts and must be considered in a comprehensive nexus management approach. [3] The nexus assessment can be deployed at different scales and systems, for example, in the Figure 1 it is shown a Water-Energy-Agriculture conceptual nexus model of a WWTP located in Jordania [4].

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Concept: Water-Energy-Food-Ecosystem (WEFE) Nexus approach

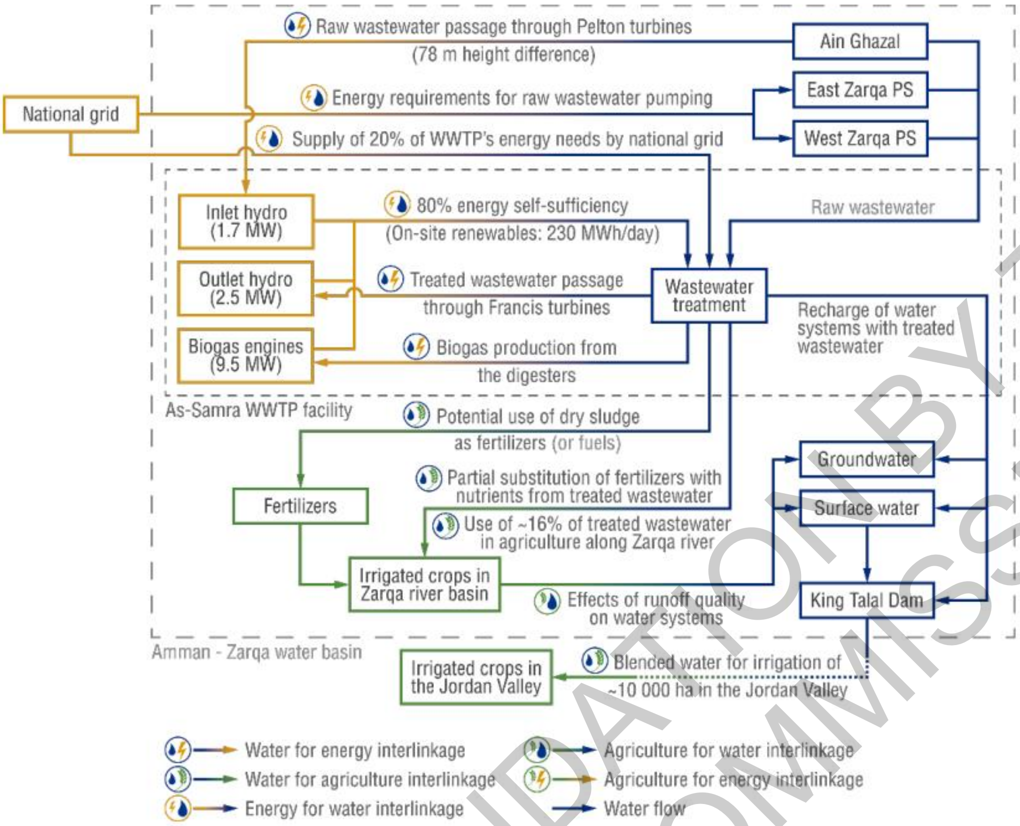

Figure 1. Graphic summary of the Water-energy-agriculture nexus interlinkages in As-Samra WWTP [4]

During the recent years, **several indices have been developed in order to characterize cities under this WEF Nexus approach**. Among them, it can be cited the UN-Habitat city Prosperity index [5] or the Nexus City Index (NXI) [3], which enable decision makers to more readily **compare global and local city resilience** without reducing the underlying complexity of the analysed WEF systems (figure 2).

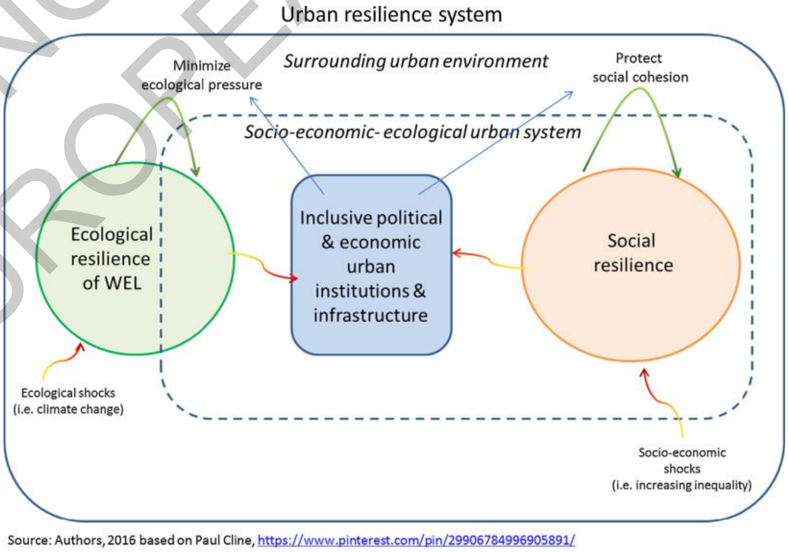

Figure 2. Urban resilience system [3]

The data sample of the European cities contains 22 cities, of which 17 cities belong to the European Union, three to the former Soviet Union, and one city each from Switzerland and Norway (see Figure

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Concept: Water-Energy-Food-Ecosystem (WEFE) Nexus approach

3). Copenhagen and Oslo are the European cities with the highest NXI of 0.948 and 0.945 of all analysed cities, whereas the cities of the former Soviet Union (Moscow and Chisinau) have the lowest NXIs in Europe. The Moscow NXI is significantly lower than those of the other European countries. This is mainly due to the fact that the equity index is extremely low. Moscow can thus be considered the least resilient city in Europe. The range of the European values is 0.204. Considering only EU countries reduces the range to 0.112. The institutional framework of the European Union leads to a more coherent development of the European cities [3].

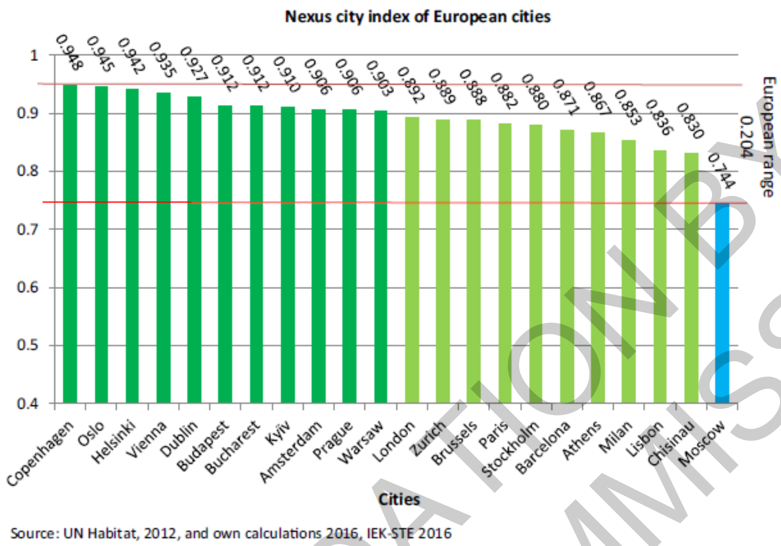

Figure 3. Nexus city Index of European Cities

THEMATIC AREA	**Circular Economy**
CO-BENEFITS	Nexus City index provides an opportunity to **operationalize equity in the nexus analysis.** This approach provides urban institutions with relevant information for the development of **political measures** to start closing the prosperity and nexus gap.
EXTERNAL LINKS	• [1] Karabulut, A.A. *et. al*. (2019). Assessing the policy scenarios for the EWFE nexus in the Mediterranean region. *Ecosystem Services*, 35, 231-240. • [2] Saladini F. *et al*. (2018). Linking the water-energy-food nexus and SDGs for the Mediterranean Region. *Ecological Indicators*, 91, 689-697. • [3] Schlör, H., *et. al*. (2018), The FEW-Nexus city index – Measuring urban resilience, Applied Energy, Volume 210, 382-392, ISSN 0306-2619, https://doi.org/10.1016/j.apenergy.2017.02.026. • [4] http://kth.diva-portal.org/smash/get/diva2:1236635/FULLTEXT01.pd • [5] UN-HABITAT. State of the world's cities 2012/2013. Prosperity of cities. Nairobi: United Nations Human Settlements Programme (UN-HABITAT); 2012

Concept: Water-Energy-Food-Ecosystem (WEFE) Nexus approach	
PRE-CONDITIONS & ENABLING CONDITIONS	***Urban from and layout:*** Nexus approach can be deployed in any city, regardless of their size, location, climate or socioeconomic conditions. ***Policy and regulatory framework:*** Nexus collaborative models or processes entail high-level political will supported by a sound governance system. The nexus approach acts as a platform for synergistic decision-making, where diverse stakeholders are actively engaged

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Concept: Water-Energy-Food-Ecosystem (WEFE) Nexus approach	
	through an inclusive process of dialogue supported by reliable science, data evidence and scenario building
CONSTRAINTS/ BARRIERS for implementation	The main barriers and challenges affecting the nexus **operationality** are: data and knowledge gaps on the interactions between nexus sectors (interlinkages); • Need for holistic analysis which provides coherence between land-use and spatial planning, hence promoting a socially acceptable allocation of resources; • Lack of systematic tools to address all the trade-offs involved in the nexus and • Lack of solutions to effectively overcome social, economic or technical barriers that hinder a real implementation of the nexus approach.
INSTRUMENTS/ Processes for implementation	***Educational, Capacity Building instruments*** • Supporting municipalities to monitor resource flows in line with impact targets and measurement processes: https://netzerocities.app/resource-1528 • Capacity building and engagement with municipalities to identify and co-create circular solutions and roadmaps: https://netzerocities.app/resource-1548 • Capacity building for city officials to understand urban metabolisms and circular solution opportunities: https://netzerocities.app/resource-1568 ***Planning instruments:*** • Integrated land use and urban planning with energy and climate: https://netzerocities.app/resource-1678 • Integrated land use planning and urban space management with mobility planning: https://netzerocities.app/resource-1688 • City water resilience assessment: https://netzerocities.app/resource-1738 ***Technical instruments:*** • Urban metabolism mapping: https://netzerocities.app/resource-1893
IMPACTS (Indicators & DNSH)	The WEF nexus approach operationalized by the different Nexus indices can serve decision makers to **identify and monitor developments** in target cities, where the early implementation of measures is necessary in order to prevent or counter steer unsustainable developments which pose a precarious threat to social or ecological stability (see Figure 4). Also, the Nexus approach can provide **information for planning and managing the urbanization process** of the cities of the world with a special focus on development in the FEW nexus sectors. Figure present the trade-offs and synergies between energy security and food insecurity in the communities of Hamburg and Melani in South Africa. The results indicate that the relationship between energy security and food insecurity combined has the following trade-off effects: For every 1% increase in the usage of an electric stove to cook, the MEPI (energy poverty) increases by 0.93%, while a 1% increase in additional measures of energy sources, the MEPI (energy poverty) decreases by 0.53%. For every 1% increase in the MEPI, food insecurity increases by 0.03%.

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Concept: Water-Energy-Food-Ecosystem (WEFE) Nexus approach

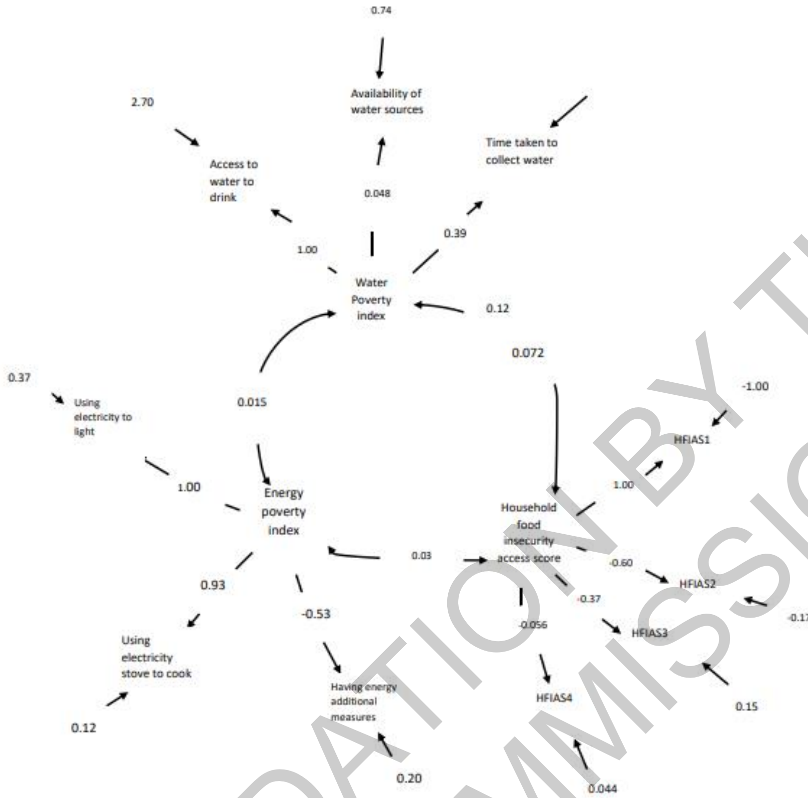
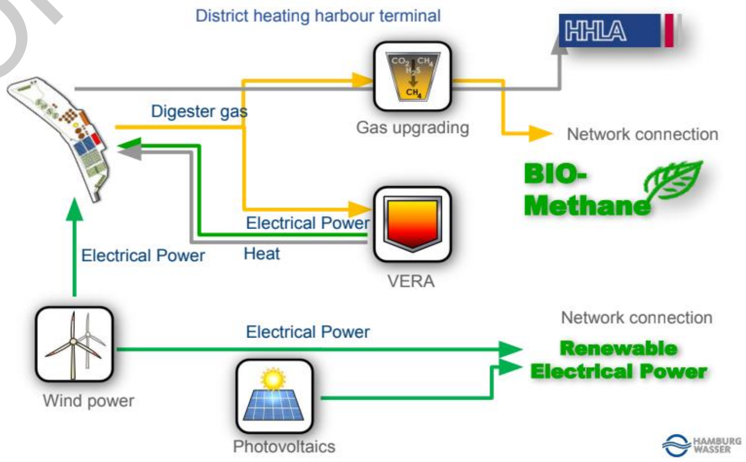


Figure 4. The interrelationship between water-energy and food security in Melani and Hamburg communities

Additional information from CASE STUDIES

Implementation examples of the WEF nexus into a city, involving holistic, integrated planning, largely influencing a city's infrastructure. It is also about opening up to innovative solutions and thinking in a less linear and more circular way. Some examples:

- **Household water-energy-food security nexus**: Empirical evidence from Hamburg and **Melani** communities in South Africa in https://uploads.water-energy-food.org/ijds-v10n8-02.pdf
- **Hamburg**: Energy efficiency improvement in the waste water treatment plant of Hamburg. https://drive.google.com/file/d/1HksBzwEIzWlluyPED7wAiLIlL-TDLk5d/view



- **Medellín (Colombia):** the city has implemented a "Green Corridors" project, which aims to create interconnected green spaces that provide food, water, and energy resources. The project includes urban gardens,

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Concept: Water-Energy-Food-Ecosystem (WEFE) Nexus approach	
	green roofs, and solar panels. https://www.c40knowledgehub.org/s/article/Cities100-Medellin-s-interconnected-green-corridors?language=en_US • **Copenhagen**: installation of a city-wide stormwater management system, which also helps reduce energy usage in the city: https://climate-adapt.eea.europa.eu/en/metadata/case-studies/the-economics-of-managing-heavy-rains-and-stormwater-in-copenhagen-2013-the-cloudburst-management-plan • **London**: thermal energy generated by the metro system is used to provide heat and hot water for several hundred homes. https://www.nytimes.com/2021/12/22/world/heat-carbon-emissions-cities.html • **Stockholm**: cold water is used in data centres to stop servers from overheating, and is then redistributed for heating homes. https://www.bbc.com/future/article/20171013-where-data-centres-store-info---and-heat-homes Other: • http://ifwen.org/#case-studies

4.1.8 Concept: Urban green space ecology

- Authors: **CEREMA**
- Knowledge Repository link: **https://netzerocities.app/resource-3308**

Concept: Urban green space ecology
From the land use planning perspective, urban green spaces or urban green areas are defined by Corine Land Cover classification[14] as "*Areas with vegetation within or partly embraced by urban fabric. This class is assigned for urban greenery, which usually has recreational or ornamental character and is usually accessible for the public, and can also include small water bodies. It includes parks, gardens, city squares with greenery, vegetated areas, cemetery with vegetation, green inner spaces of city blocks, ponds, lakes, small water bodies*". However, instead of considering them as individual and disconnected green spots, all these green and blue areas can together form a green infrastructure whose roles and functions should be seen as an ecosystem. As summarised by the European Environment Agency[15], "*Green infrastructure is a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services (as defined by the EC's GI communication – COM/2013/0249final). Green infrastructure is present in both rural and urban settings. In urban areas, many different features may be part of green infrastructure (e.g. parks, gardens, grassy verges, green walls or green roofs) as far as they are part of an interconnected network and are delivering multiple ecosystem services. These green urban elements (or blue if aquatic ecosystems are concerned) may be found within the city and in its peri-urban area*" (source: EEA, glossary of green infrastructure). They are therefore relying on nature-based solutions. IUCN defines nature-based solutions as "*actions to protect, sustainably manage, and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously benefiting people and nature*."

[14]https://land.copernicus.eu/user-corner/technical-library/corine-land-cover-nomenclature-guidelines/html/index-clc-141.html
[15]https://www.eea.europa.eu/themes/sustainability-transitions/urban-environment/urban-green-infrastructure/glossary-for-urban-green-infrastructure

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Concept: Urban green space ecology

Greening through the creation of urban green spaces can therefore provide multiple ecosystem services and is a response to the challenges of biodiversity and climate change. Climate change reinforces certain hazards that are already problematic in the urban environment: overheating in summer, extreme rainfall causing flooding by runoff on impermeable surfaces, etc. The physical and physiological properties of green spaces make it possible to limit certain hazards: shading and leaf transpiration for cooling are examples. Thus, greening is now recognised as a possible response to the challenges of biodiversity loss and climate change.

The purpose of this concept sheet is to highlight the role and functions of green and blue areas in cities as part of an ecosystem.

CO-BENEFITS

Urban green and blue spaces within the city contribute to enhance benefits provided by natural ecosystems. These co-benefits can be maximised if green and blue areas are integrated at the earliest stage during the planning and development process.

Development of biodiversity: urban green spaces are a support for living fauna and flora in the city, whether plants or animals. These spaces are at the same time refuges, a source of food, living places for animal and plant species present in the city, but also vectors of pollination. They therefore ensure the proper functioning of ecosystems and thus enable all other services to be provided.

Food supply: food species can be planted in urban green spaces. Thus, they contribute to the development of public space while offering a moment of conviviality and sharing.

Air quality: green areas have an important role in absorbing air pollutants and cleaning air.

Storm water management: urban green areas, when impervious areas, contribute to limit water run-off and absorb storm water. They participate to reduce the amount of rain water sent to water piped network.

Social link and living environment: urban green spaces are recreational places (outdoor activities, sports and art) and meeting places for everyone. They improve the quality of the living environment, and can also play a role in tourism attractiveness.
Health of the population: the reduction of the urban heat island effect and the risk of flooding due to runoff, as well as the improvement of air quality, social links and the living environment contribute to the good health of the inhabitants. Urban green

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Concept: Urban green space ecology	
	areas facilitate the practice of sport and outdoor activities within cities and therefore enable physical activities and stress reduction. **Noise reduction**: green areas can contribute to reduce noise within cities that affect health.
KEYWORDS	Nature-based solutions – Green and blue infrastructure and network – ecosystem services
EXTERNAL LINKS	• **Nature4cities**, a nature based solutions knowledge diffusion and assessment platform for renaturing cities: https://www.nature4cities.eu/ and its platform: https://nbs-explorer.nature4cities-platform.eu/?hl=en • **Network nature: https://networknature.eu/**: NetworkNature is a resource for the nature-based solutions community, creating opportunities for local, regional and international cooperation to maximise the impact and spread of nature-based solutions. The project is funded by the European Commission under the Horizon 2020 programme. • **Connecting Nature, https://connectingnature.eu/** Connecting Nature is a five-year project funded by the European Commission's Horizon 2020 Innovation Action Programme. • **Naturvation: https://naturvation.eu/**: NATure-based URban innoVATION is a 4-year project, funded by the European Commission and involving 14 institutions across Europe in the fields of urban development, geography, innovation studies and economics. We will seek to develop our understanding of what nature-based solutions can achieve in cities, examine how innovation can be fostered in this domain, and contribute to realising the potential of nature-based solutions for responding to urban sustainability challenges by working with communities and stakeholders. • **Urban GreenUP : https://www.urbangreenup.eu/** : URBAN GreenUP s a EU-funded project which aims at developing, applying and validating a methodology for Renaturing Urban Plans to mitigate the effects of climate change, improve air quality and water management and increase the sustainability of our cities through innovative nature-based solutions • **MOOC Nature For City Life**: https://moocnatureforcitylife.eu/ • **World Health Organization, regional office for Europe (2017),** Urban green spaces: a brief for action, https://www.euro.who.int/__data/assets/pdf_file/0010/342289/Urban-Green-Spaces_EN_WHO_web3.pdf • **UnaLab** : https://unalab.eu/en, The UNaLab project contributed to the European knowledge base on nature-based solutions (NBS), by demonstrating their benefits, cost-effectiveness, economic viability and replicability through the co-creation and implementation of NBS in three front-runner cities, Eindhoven, Tampere and Genova. The front-runner cities actively collaborated and shared their experiences with seven follower cities Stavanger, Prague, Castellón, Cannes, Başakşehir, Hong Kong and Buenos Aires, as well as two observers Guangzhou and the Brazilian Network of Smart Cities.

Concept: Urban green space ecology	
PRE-CONDITIONS & ENABLING CONDITIONS	***Climate and geography*** Cities can be a hostile environment for the proper development of vegetation. There are many sources of occasional or long-term stress: air and soil pollution to which species can be more or less sensitive, poor water supply, intentional or accidental damage. In urban environment, air is drier, the sunshine is often too direct, but also sometimes too weak. Soils can be inhospitable: compacted, compacted, too filtering, poor, polluted, ... Buried networks and pavements make rooting difficult and inefficient. Older plantations, when they include only one species, can make the plant heritage particularly vulnerable to diseases and pests. Species are not

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<tr><th colspan="2">Concept: Urban green space ecology</th></tr>
<tr><td></td><td>equal in coping with these difficulties. They develop different strategies for adaptation:
• To the local climate: a species located in its natural area will have a better resistance to local conditions. However, this must be put into perspective because of the specificities of the urban environment and the effects of climate change.
• To the specificities of the urban environment: some species are more tolerant than others of compact and dry soils, pollution and injuries. They are therefore better adapted to this urban context.
• Expected climate change: Climate change has multiple and varied consequences depending on the territory: increased water shortages over longer periods, increased soil salinity and frequency of storms on the coast, forest fires in areas not previously affected, etc. The species must therefore be adapted to these local effects.
It is necessary to know these adaptation strategies and to optimise them to ensure the resilience of urban green spaces.

Policy and regulatory/legal framework:
Territories are confronted with contradictory issues between the availability of land, the incentive to drastically reduce artificialization and a growing demand for green spaces by citizens. The implementation of nature projects must become a structuring element of urban planning. Nature issues should be treated on an equal footing with more traditional issues such as housing, facilities, shops and mobility. Another major challenge is to avoid building on the soils that are most suitable for vegetation or most likely to infiltrate rainwater. Indeed, when they have access to water and a living soil, vegetated developments provide optimal services. A land strategy based on the ecological potential of soils, backed up by planning, becomes an essential lever for identifying and reserving spaces for renaturing the city. Under these conditions, nature could become the basis of a new "ecological urbanism" that would structure spaces and mobility. It is therefore essential to give nature a place of its own so that it can contribute to a liveable, vibrant, resilient and sober city.

Project governance and implementation modalities:
This approach, which aims to make nature a pillar of a climate-neutral city, shall bring together the various skills and forces present in the territory. It shall be based on natural ecosystems already in place, which are the real actors to be preserved as a priority. The objective is to adopt an integrative approach that considers the city and its ecological and climatic realities (3).
The successful integration of nature as a component of a new urbanism is conditioned by the implementation, acceptance and maintenance of natural facilities, in a long-term perspective and a global strategy.
This strategy could be based on three phases:
• Developing a nature project: sharing ambitions and overcoming opposition
• Survey the existing fauna, flora and habitats and identify the land that can be mobilised
• Define development actions for and with nature by preserving the existing, adopting protection rules, favouring the systematic integration of nature, creating nature spaces and anticipating the reserve of space through planning.</td></tr>
<tr><td>CONSTRAINTS/ BARRIERS for implementation</td><td>Project governance and implementation modalities:
The design and implementation of urban green areas shall involve multiple stakeholders within the city administration (urban planning, landscape, water management, etc). Services involved in the maintenance and management of green public spaces shall be involved from the beginning of the project to determine the needs and constraints of the projects and the choice of species to be planted.

Climate / Geography:</td></tr>
</table>

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Concept: Urban green space ecology	
	Location of green areas, as well as the choice of plants and trees species shall result from an assessment and site diagnosis (environmental conditions, soil conditions, geographic and climatic conditions, landscape environment, etc). An assessment of current and future climate should be undertaken to identify appropriate local species. ***Green and blue network:*** Urban green areas shall not be considered and designed as isolated spots but rather as being part and connected to a larger blue and green network. Therefore, they shall contribute to the continuity of this green and blue corridor. ***Policy / regulatory framework:*** Land pressure for urban development can reduce the opportunities for development of urban green areas within urban settlements. Integration of urban green areas as a key parameter for resilient and sustainable urban development shall be clearly highlighted with the land-use planning documents including limitations for future development (no construction areas, buffer areas, etc). The explanation of ecosystem services provided by the urban green areas can help to demonstrate their value for city development. ***Urban form and layout:*** Available urban spaces and urban form (building height, setback between buildings, depth of open ground, etc) will influence the needs and constraints of the project. They shall be carefully analysed to determine the key principles for planting. ***Social context:*** Participation with citizens is required to design these areas as multifunctional spaces.
INSTRUMENTS/ Processes for implementation	• NBS and Green Infrastructure plans and strategy design and governance: https://netzerocities.app/resource-1823 • NBS and Green Infrastructure regulation and ordinances: https://netzerocities.app/resource-1813 • Integrated climate plans for cities (i.e. SECAPs): https://netzerocities.app/resource-1698 • Integrated land use and urban planning with energy and climate: https://netzerocities.app/resource-1678 • Educational activities on NBS: https://netzerocities.app/resource-1518 • Supporting municipalities to monitor resource flows in line with impact targets and measurement processes: https://netzerocities.app/resource-1528 • Engagement, co-creation and co-design of NBS and Green Infrastructure plans and interventions: https://netzerocities.app/resource-1608 • NBS and Green Infrastructure Mapping: https://netzerocities.app/resource-1863 • City water resilience assessment: https://netzerocities.app/resource-1738 • City coaching in NBS: https://netzerocities.app/resource-1618 • Platform for Enhancing Multi Stakeholder Dialogue to Implement NBS across EU: https://netzerocities.app/resource-1628 • Public procurement for innovative NBS and Green Infrastructure interventions: https://netzerocities.app/resource-588
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	***Economic and social context*** Distribution of green areas within the city shall be planned considering the most vulnerable social groups in order to ensure they have access to these areas. ***Risk of maladaptation***

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<table>
<tr><th colspan="2">Concept: Urban green space ecology</th></tr>
<tr><td></td><td>While nature-based solutions (including urban green areas) can contribute to climate adaptation, adverse effects shall be anticipated to avoid maladaptation: increase of water demand for watering needs of plants.

Management / maintenance of green areas
Resources needed for maintaining green areas shall be anticipated and planned and sufficient capacities allocated to that purposes.</td></tr>
<tr><td>IMPACTS (Indicators & DNSH)</td><td>Adaptation to climate change:
Green spaces help to cool the surface and ambient temperatures of urbanised areas through the shade and evapotranspiration they generate. They can therefore contribute to reducing localized situations of climatic discomfort, or even limit the urban heat island effect. This service is maximised by the choice of large trees with dense foliage, capable of maintaining their transpiration for a long time on dry ground without endangering themselves. Shrubs are also relevant options: if the plantings are massive, evapotranspiration can contribute significantly to localised cooling. However, the benefits of green spaces are only possible if the vegetation is healthy and supplied with water according to its needs, so as to achieve maximum transpiration. The proper development of this vegetation and sensible pruning practices also increase these positive effects.

Flood risk management:
Plants are major consumers of water, particularly through transpiration: by consuming water in the soil, they maintain infiltration capacity. Indeed, rainwater does not infiltrate, or only slightly, into a saturated soil, which therefore causes runoff. Species that consume large quantities of water may be of interest: the more water the tree consumes and transpires, the less saturated the soil surfaces will be when it rains. However, it is prudent to choose species that are able to transpire abundantly and tolerate dry soil. Plants can also reduce runoff by retaining some of the rain directly in their foliage through interception. However, some of the water does reach the soil: plants can then facilitate infiltration via their roots. A well-developed and dense root network maintains more porosity, and therefore infiltration. Trees and shrubs can have contrasting tolerances to soil moisture, especially when the water content is so high that it prevents gas exchange between the roots and the soil. Species should therefore be chosen to suit the site conditions, especially if rainwater is to be concentrated in the site. Properly chosen, trees and shrubs can be placed directly in water management structures such as swales, where they improve performance by intercepting and maintaining infiltration potential.

Air quality improvement:
Urban green spaces contribute to improving air quality. They intercept particulate air pollutants such as nitrogen dioxide or ozone. Some plants even have the advantage of having rough, hairy or even wax-covered leaves and will retain these particles more durably, as they are otherwise quickly carried away by the wind or precipitation. It is necessary to remember that even if these effects are proven, they are in proportions far below the emissions linked to human activities. Revegetation alone will not solve the air quality problems of a city. It is important to specify that the effects of vegetation on the concentration of pollutants in the air in a very localised manner are difficult to anticipate: they depend on the shape of the trees, the shape of the surrounding buildings, the air circulation, etc. In certain configurations, the barrier effect of vegetation can increase the concentration of buildings. Finally, some species have a certain duplicity, since they are characterised, in particular in case of stress, by high emissions of volatile organic compounds, themselves precursors of ozone.</td></tr>
<tr><td></td><td>Examples of proposed indicators:
• Proportion of urban green areas within the city boundaries in relation to the total area
• Canopy ratio within the urban settlement</td></tr>
</table>

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Concept: Urban green space ecology	
	• Distribution of urban green areas within the city boundaries (or average distance to the closest green area) • Average urban green area per inhabitant (i.e. total urban green areas / total population)

4.1.9 Concept: Carbon capture and storage (CCS) and utilisation (CCU)

- Authors: **South Pole**
- Knowledge Repository link: https://netzerocities.app/resource-3318

Concept: Carbon capture and storage (CCS) and utilisation (CCU)	
Carbon capture and storage (CCS) and utilisation (CCU) present themselves as crucial solutions in the emission reduction strategies for hard-to-abate industries that have few other decarbonization options, such as chemical, cement and steel production. It can also be used in the production of hydrogen. CCS technologies prevent fossil-based CO_2 from entering the atmosphere by capturing it at the source and storing it safely underground, so that it does not contribute to climate change. It involves three steps: during **capture**, the CO_2 is separated from other gases produced at large industrial facilities, such as steel mills, cement plants, petrochemical facilities, coal, and gas power plants; post-capture, the CO_2 is compressed for **transportation**, then dehydrated and sent towards the storage site generally through pipelines or ship; for safe and durable **storage,** the CO_2 is injected deep underground into rock formations (saline aquifers) and depleted oil and gas fields. In the case of CCU, the captured CO_2 is reused into useful products where it can be stored durably, such as cement, ceramics or aggregates. In its 2020 Energy Technology Perspectives report, the International Energy Agency (IEA) acknowledges CCUS as one the four pillars of the global energy transition, alongside electrification coupled with renewables uptake, bioenergy and hydrogen, due to its role in reducing emissions from large power stations and industrial plants. Despite recognition of their unique role in decarbonization, the deployment of these technologies has been slow, with less than 0.5% of annual global investment in clean technologies being allocated to CCUS, and therefore with limited impact on global CO_2 emissions. For CCS and CCU to reach their full decarbonization potential, challenges related to policy and regulatory support, social acceptance and costs of the technologies will need to be overcome. With cities typically being large industrial centres, as well as centres for innovation, they are great candidates for integrating CCS and CCU in their decarbonization strategies.	
CO-BENEFITS	• Overall positive effect on air pollution. • For CCU, enabling the development of a circular economy. • Transition option for industrial regions. • Preserving or creating employment.
KEYWORDS	• Industrial emissions • Industrial decarbonization • Carbon prices • Emission reductions • Durable storage • Permanent storage • CO_2 transport • Cement decarbonization • Steel decarbonization • Hydrogen production

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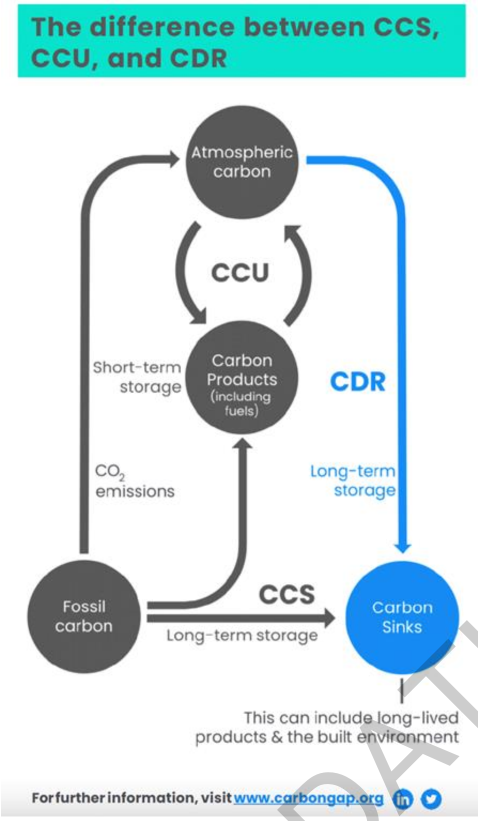
Concept: Carbon capture and storage (CCS) and utilisation (CCU)	
EXTERNAL LINKS	 *CarbonGap, 2022*
EXAMPLES	[***Carbon Neutral Cities***](): As part of the Carbon Neutral Cities Alliance (CNCA), five cities (Amsterdam, Copenhagen, Helsinki and Oslo) have collaborated on a one-year project exploring CCS and CCU technologies and the solutions they provide to cities: Amsterdam's Climate Neutral 2050 Roadmap includes carbon capture storage and use technologies.

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Concept: Carbon capture and storage (CCS) and utilisation (CCU)	
PRE-CONDITIONS & ENABLING CONDITIONS	***Technical aspects/infrastructure:*** The technology is tested and proven, with 19 operating full-scale projects world-wide. The presence of heavy industry or fossil power plants in cities or in its proximity makes the case for CCS and/or CCU very clear, as they are often the only available solution for significant emission reductions, and even the cheapest option for deep decarbonization for several industrial sectors. Access to transport infrastructure to transport the CO_2 to long-term storage sites (depleted oil and gas fields, saline aquifers) is a key enabler of CCS. The proximity to or the accessibility of durable storage is also an important factor. ***Policy and regulatory/legal framework:*** • Quantified targets for CCS and CCU in climate-neutral roadmaps, including at city level, would support targeted investments in these technologies. • Carbon pricing is an important incentive for (retro)fitting power generation or industrial infrastructure with CCS. • In the EU, the regulatory framework relevant for CCS includes the EU ETS Directive (2003/87/EC) and its Monitoring and Reporting Guidelines

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Concept: Carbon capture and storage (CCS) and utilisation (CCU)	
	(2010/345/EU), the Liability Directive (2004/35/EC) and the CCS Directive (2009/31/EC). • At city level, additional support measures are the inclusion of provisions for carbon capture in spatial planning and permitting discussions and by facilitating transportation routes from the capture point to the storage site, which is most likely to be located outside of the city. For CCU, mandating zero or near-zero building materials would support the business case for this technology. ***Funding and financing:*** • Public funding support schemes, similar to the recent example in Denmark that presented a EUR 1.1 billion budget for CCS, meant to increase investor confidence in CCS and reduce costs for future applications. From a cities' perspective, they can support building a business case for CCU through indirect measures such as showing the willingness to pay slightly more for these products and by mandating zero or near-zero building materials. • In the case of CCU, it can also generate revenues from selling the captured CO_2 toward its potential uses. • Additional carbon finance through voluntary carbon markets. ***Project governance and implementation modalities:*** • Public-private partnerships • Stakeholder consultation and engagement
CONSTRAINTS/ BARRIERS for implementation	**High upfront costs** for CCS installations, and the absence of a by-product makes it hard to be commercially viable in the absence of carbon pricing. A carbon price that is too low would also not be enough to incentivize the application of CCS. **Public acceptance** is lower than that of other emission reduction technologies, with a key reason being the perceived risk of prolonging existing fossil fuel infrastructure instead of investing in radically transformative measures.
INSTRUMENTS/ Processes for implementation	***Enabling instruments:*** Capacity building and training: https://netzerocities.app/resource-1578 Educational/capacity building barriers identification: https://netzerocities.app/resource-158 ***Planning instruments:*** Decarbonization plans for industry: https://netzerocities.app/resource-1718 Integrated climate plans for cities: https://netzerocities.app/resource-1698 ***Policy instruments:*** Governance EU climate neutrality framework: https://netzerocities.app/resource-1728 ***Regulatory instruments:*** Building Material Passport (BIM-based): https://netzerocities.app/resource-1833
DRAWBACKS/ ADVERSE IMPACTS of the solutions after implementation	The main drawbacks of CCS are the additional costs that it adds to power generation or to the industrial processes, and the risks of leakage during transportation or at the storage site, which would reverse the climate benefits of the technologies. Major concerns are related to the leakage out of the underground reservoirs into the air or in the nearby water supplies, or the possibility of induced seismicity. Robust monitoring, verification and reporting systems will be required to mitigate these risks.
IMPACTS (Indicators & DNSH)	***GHG emissions avoidance:*** 600 billion tonnes of CO_2 avoided by retrofitting existing power and industrial plants, according to the IEA. ***Costs:***

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	For industrial processes, current costs range USD 20–90 per ton, depending on the concentration of the CO_2 stream. For power generation and steel production, the costs are in the range of USD 75–120 per ton.

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5 Next Steps

The task 10.2 is over with the submission of the present document and the upload of all resources included in here in the NZC Knowledge Repository. However, it will be a continuously updating of contents in the knowledge repository, mainly by adding of case studies and examples. Going forward, the Factsheets will undergo continuous updates that will incorporate examples from NetZeroCities pilots as well as examples that cities are eager to share. The Knowledge Repository is an accessible resource in the NetZeroCities portal.

In the context of the whole WP10, services are being developed to make more actionable and useful the overall Solutions Catalogue, mainly to ease the search of solutions based on characteristics or needs/ barriers of the cities, or by generating groups of solutions that are better implemented together as bigger interventions in cities. The services provided will be part of the *Capability Learning Programme* of other WPs, as the services will help cities in their climate neutrality journey with information and dedicated workshops to co-design the portfolio of solutions, address the emissions and sectors included in their *Emission Inventory*, and identify barriers, opportunities and co-benefits. The services will be potentially integrated, through WP3, in the Portal to have a more visual and accessible Knowledge Repository.

Service: Bundles of solutions

To address complex urban problems, cities require a multi-lever approach that goes beyond any single solution. This means that several solutions across levers (bundling policies, social innovations, financing instruments, etc.) can more effectively tackle complex issues that require a range of (technical) interventions.

Bundles of solutions can reinforce interconnections and underpin synergies, creating a more comprehensive and effective approach. Finally, bundles of solutions can lead to a greater stakeholder engagement and participation in problem-solving, as by involving different actors in the process, more inclusive and effective solutions can be addressed.

The following Bundles of solutions will be available:

- **RES Generation – Low Carbon Electrification**: focusing on RES generation, all sectors are electrified and connected in a smart way with low carbon technologies.
- **RES Generation – Low Carbon Energy via Sector Coupling**: it focuses on the importance of connecting sectors through the different energy streams (heating, cooling, fuels, and electricity), and, when electrification is not possible, other fuels (such as hydrogen) will be used. Circular Economy is seen as cross-cutting and a way of reusing waste from one sector to another.
- **Energy Efficiency – Reduction of Energy and Resources needs**: mainly focusing on "passive" solutions towards the reduction of energy needs in the built environment, as well as incorporating the circular economy approach to include the resource efficiency as well.
- **Carbon Capture, Storage and Removal**: focused on the reduction of energy needs in the built environment through carbon sinks, as well as on removing residual emissions from the power, transport and industry sector.

Service: Gap analysis (Self-assessment tool)

The tool is designed as a searchable database that allows users to filter interventions based on criteria such as sector, barriers or co-benefits to be obtained. It currently includes the Solutions Catalogue present in this document, but can be expanded to include other sources of information as well.

Users can filter interventions based on their specific needs and interests, making it easier to find solutions that are relevant to their context. The tool generates a list of solutions that have been successful in addressing similar challenges, providing cities with a range of inspiring examples to draw from.

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In addition to aiding in the search for solutions, the tool can also assist in portfolio definition. By allowing users to filter interventions based on specific criteria (co-benefits, barriers, sectors, etc.), the tool can help identify a portfolio of interventions that work together to address a particular challenge in a comprehensive and effective manner.

Therefore, the tool will:

- **Improved decision-making**: The tool can help policymakers, practitioners, and researchers make more informed decisions about which interventions are most effective in addressing specific social, economic, and environmental challenges. By providing a comprehensive overview of existing interventions across multiple sectors, the tool can help identify gaps and overlaps in intervention strategies, which can inform the development of more effective interventions
- **Resource optimization**: The tool can help optimize the allocation of resources across sectors by identifying interventions that have been successful in addressing similar challenges. This can help reduce duplication of efforts and resources and maximize the impact of interventions.
- **Collaboration and learning**: The tool can facilitate collaboration and learning across sectors by promoting knowledge-sharing and cross-sectoral dialogue. By providing a platform for stakeholders to share information and insights about interventions, the tool can help build a more collaborative and coordinated approach to addressing complex social, economic, and environmental challenges.

In the future, the tool could also include a range of features, such as case studies, or estimated evaluation of solutions, as well as links with other resources across levels, to provide users with a more comprehensive understanding of the effectiveness of different interventions.

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Conclusions

Despite the immense potential for decarbonising cities, there are still barriers for the adoption of technologies, such as lack of knowledge and expertise, limited space, funding constraints, technical, low social acceptance, or inadequate policy and regulatory frameworks. However, several strategies can overcome these barriers and promote the uptake of solutions. For instance, capacity-building programs, such as energy offices or local strategy documents, can enable stakeholders to develop the knowledge and skills necessary to implement solutions effectively. Incorporating specific training or awareness campaigns in schools can also enhance public awareness and engagement. Mobilizing collective knowledge and skills, such as manpower, can further support the development and implementation of solutions. Multiple-use of space, including the use of roofs or facades for solar panels or vertical farming, can optimize land usage in cities and reduce the stress of space. Access to funding, such as public or EU funding or through incentives and new business models, can help overcome financial barriers. Monitoring the status of facilities through data collection and predictive maintenance can prevent technical failures and prevent high running costs.

Furthermore, collaborative development and governance, including the involvement of relevant stakeholders from the outset, can foster co-design and enhance adoption. Policy and regulatory frameworks, such as local ordinances or incentives, can accelerate or hinder the uptake of solutions. For instance, the current legalisation hinders the selling of electricity to neighbouring plots; and the taxation of the capacity limits small-scale power generation. Lots of variation in national level regulatory barriers, depending on the level of development in the country. For instance, restrictions on materials with high embodied emissions, tax reductions from collective solar installations, green public procurement, and relevant EU/national standards and regulations can all promote the adoption of certain technologies.

Low social acceptance may be linked to the perception of high investment costs, long payback periods, and lack of proper business models. Therefore, activities aimed at disseminating information about the solutions should focus on tackling these issues as well as implementing demonstrations that test solutions and show the benefits to a wider public, or co-designing with them the portfolio through city assemblies or participatory budgets.

The experience of EU Covenant cities demonstrates the need for strong policy support, partnerships with citizens and local businesses, and the establishment of regulations and urban planning principles that support sustainable practices. By understanding the enabling conditions and barriers that can affect a city per solution (in each Factsheet), policy-makers and stakeholders can learn from it, identify potential challenges and opportunities and make informed decisions about how to support the implementation of solutions. The deliverable addresses this issue by providing a comprehensive catalogue of solutions to address GHG emissions in cities, organised around eight thematic areas. Each solution is described in a Factsheet, which includes detailed information about the solution and its co-benefits (coming from D10.2), and outlining the design environment conditions for each solution, including pre-conditions, enabling conditions, constraints/barriers, instruments/processes for implementation, drawbacks/adverse impacts, and impacts.

The Solutions Catalogue aims to inspire cities by aiding in their search for solutions to reduce emissions and establish climate neutrality. But the Solution Catalogue needs to be combined with enabling factors across levers (policy measures, social innovation measures, stakeholder engagement, or financing instruments), to facilitate the adoption and implementation of solutions. Ultimately, the impacts of each solution and its co-benefits can help cities identify which solutions to include in their portfolio of actions towards climate neutrality while ensuring the DNSH principle is respected.

By tackling barriers through the strategies outlined in this document (per solution), cities and districts can successfully adopt sustainable solutions that enhance quality of life, economic prosperity, and environmental sustainability

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References

As the present document contains the whole catalogue of solutions integrated within, there are plenty of references for each of the more than 170 solutions, and 9 concepts, both for the state-of-the-art solutions and description and for the examples of case studies on the deployment and implementation of such solutions in cities/pilots, etc.; those are referenced in the Factsheets themselves, as well as will be added to the corresponding link in the Knowledge Repository. Thus, the references below are only from the complementary sections in this deliverable.

- Info Kit for Mission Cities (EC): https://ec.europa.eu/info/sites/default/files/research_and_innovation/funding/documents/ec_rtd_eu-mission-climate-neutral-cities-infokit.pdf
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- IPCC, 2022: Summary for Policymakers [H.-O. Pörtner, D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem (eds.)]. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 3–33, doi: https://doi.org/10.1017/9781009325844.001
- JRC report, The Future of Cities: https://urban.jrc.ec.europa.eu/thefutureofcities/climate-action#the-chapter
- Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, amending Regulation (EU) 2019/2088. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32020R0852&from=EN

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