Final report on WP10 services

Services and resources supporting cities' climate neutrality pathways

Deliverable D10.6

Version N°1.0

Authors: Carla Rodríguez Alonso (**CARTIF**), África Sánchez Velarde (**CARTIF**), Andrea Gabaldón Moreno (**CARTIF**), Carolina García Madruga (**Tecnalia**), Maider Arana Bollar (**Tecnalia**), Manuel Benito (**Tecnalia**), Mari Hukkalainen (**VTT**), Eleni Charoniti (**TNO**), David Dooghe (**TNO**), Maiara Biscaro Uliana (**TNO**).

Disclaimer

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Abbreviations and acronyms

Acronym	Description
AI	Artificial Intelligence
CCC	Climate City Contract
DNSH	Do Not Significant Harm
GHG	Greenhouse Gas
KR	Knowledge Repository
LP	Learning Programme *(previously named as learning journey)*
NZC	NetZeroCities
PV	Photovoltaic
WP	Work Package

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Summary

This deliverable presents a practical, user-oriented guide to the suite of services and resources developed in **Work Package 10, "State-of-the-art expert services on thematic areas"** of the NetZeroCities project. These services are designed to support cities in their transition to climate neutrality by offering tools for planning, prioritisation, implementation and capacity building.

Rather than detailing project processes, this report provides a **consolidated overview of the ready-to-use services available to cities**, including links, visual aids, and tutorials to support effective uptake. It is addressed to a broad audience: Mission Cities now focused on implementing and iterating their Climate City Contracts (CCCs), Pilot and Twin Cities testing and scaling innovative solutions, and other cities across Europe looking to develop comparable climate-neutrality strategies and benefit from the NetZeroCities tools.

Keywords

Knowledge Repository; Solution Bundles; Solution Outliner; Learning Programmes; Demand-Driven Expertise; Thematic Areas; Co-benefits; Technical Innovation; Solution Factsheet; Climate-Neutral Cities.

Structure of the document

The document is organised into seven main sections and two annexes:

- **Section 1 – Introduction** outlines the context, objectives, and scope of the deliverable.
- **Section 2 - The WP10 offer at a glance** provides a quick overview of the resources and services available to cities.
- **Section 3 - WP10 Services for climate-neutral cities: what's available to you** presents each service developed under WP10 in detail, with access links, examples and tips:
    - **Section 3.1 - Knowledge Repository – access to technical solutions and real-world examples** through a structured library of resources and solution fact sheets.
    - **Section 3.2 - Solution Bundles – systemic thinking through visual solution groupings,** a visual tool to explore systemic synergies by grouping solutions.
    - **Section 3.3 - Solution Outliner – Prioritising actions based on your city's needs,** a recommendation tool that helps cities prioritise actions based on their specific contexts.
    - **Section 3.4 - Learning Programme – Formulating an integrated portfolio of actions,** capacity-building and peer-learning formats for technical topics.
    - **Section 3.5 - Demand-driven expertise – customised support for Mission and Pilot cities,** tailored support for Mission and Pilot Cities.

Figure 1 below illustrates the structure of the sub-sections within each service.
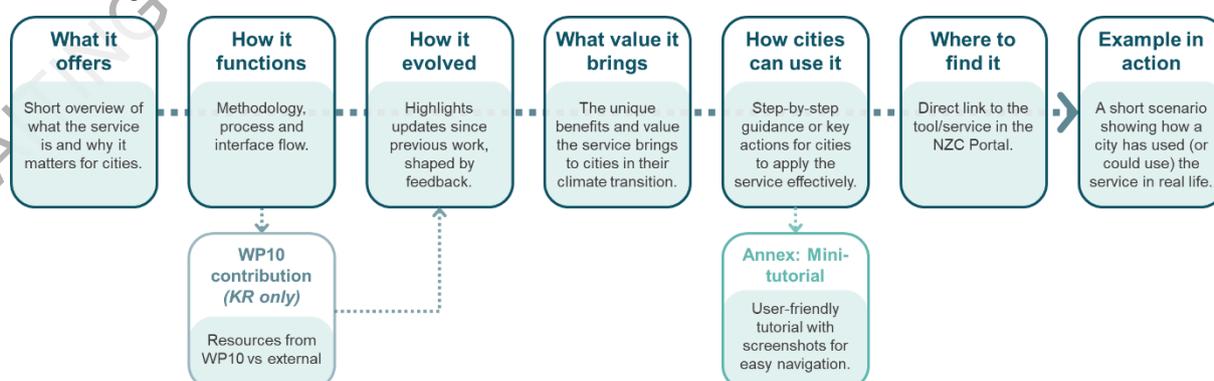
Figure 1: Structure of the services' subsections

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- **Section 4 - When to use what: making the most of the WP10 services across the climate transition** maps the services to the phases of the Climate Transition Map and provides suggestions on how to use the tools effectively, including how to combine them for greater impact.
- **Section 5 - Conclusion** wraps up with a message to cities and a call to action.

The annexes include:

- **Annex 1 - Mini-tutorials**, with visual step-by-step guides to the three key services:
    - **Annex 1.1 How to browse the Knowledge Repository**
    - **Annex 1.2 How to use the Solution Bundles tool**
    - **Annex 1.3 How to use the Solution Outliner**
- **Annex 2 - List of all factsheets and resources developed under WP10**, grouped by thematic area and linked to the Knowledge Repository.
- **Annex 3 - Tag recommendation system in NetZeroCities**, where the process carried out to define specific AI tagging models developed to ensure easier access, improve search experience and better access to most up-to-date factsheets is described.

1   Introduction

This deliverable, D10.6 "Final report on WP10 services", presents a practical guide for cities on how to navigate and benefit from the suite of technical services and resources developed under **Work Package 10 "State-of-the-art expert services of thematic areas"** of the NetZeroCities project.

Rather than a conventional project report, this document is designed as a **hands-on resource** for a wide audience of cities -whether you are a **Mission City** now focused on implementing and refining your Climate City Contract (CCC), a **Pilot or a Twin City** demonstrating scalable solutions, or a city beginning or accelerating its own climate neutrality programme, drawing inspiration from the approaches and resources used by Mission Cities, and benefit from the services created through NetZeroCities.

Over the course of the project, WP10 has focused on identifying, developing and organising technical solutions and thematic services that support systemic transformation. These services help cities:

- Plan and structure decarbonisation actions using tested Solution Bundles.
- Prioritise interventions based on local needs and context using the Solution Outliner.
- Access a rich repository of practical knowledge, factsheets and tools.
- Build internal capacity and tap into external expertise.

The tools and services highlighted in this guide -such as the **Knowledge Repository**, **Solution Bundles**, **Solution Outliner**, **Learning Programme** and **Demand-driven expert support**- were co-designed with cities and are structured to be **open, modular and adaptable**. Many are already integrated within the NetZeroCities Portal, supporting cities at various levels of engagement.

By consolidating these services in a single, user-oriented document, this deliverable aims to ensure **ongoing access, clarity and usability** for cities across Europe. It showcases not only the tools themselves, but also guidance on when and how to use them -aligned with the phases of the Climate Transition Map- and provides actionable tips and tutorials to maximise their value.

We invite you to explore this guide, make use of the services and integrate them into your city's programme toward a just, inclusive and climate-neutral future.
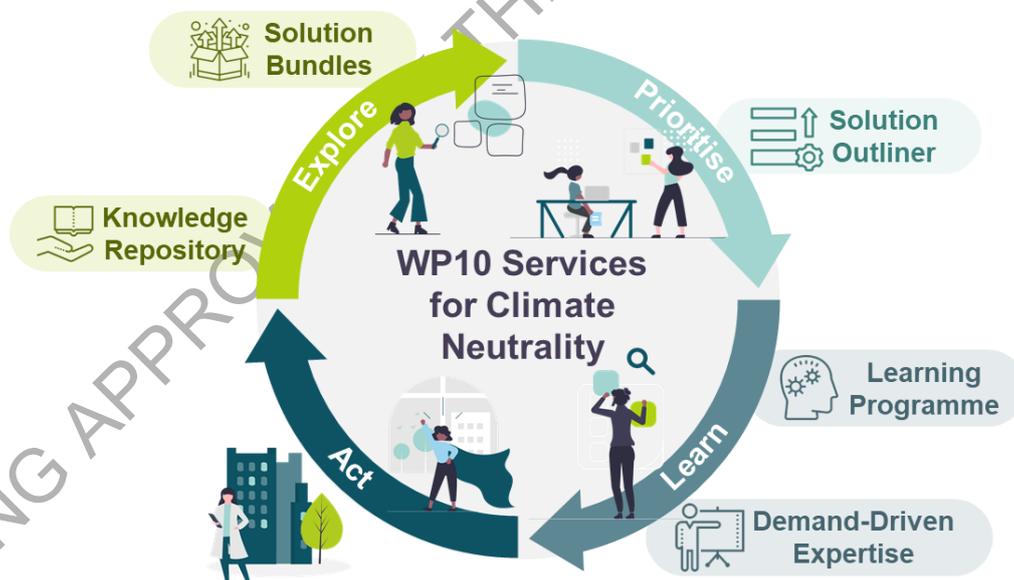
Figure 2: WP10 services help cities explore, prioritise, learn and act for climate neutrality

2   The WP10 offer at a glance

Work Package 10 of the NetZeroCities project provides a curated set of services and resources designed to support cities in achieving their climate-neutrality goals. These services are grounded in technical expertise and thematic innovation and respond directly to city needs identified through consultations, pilots and peer engagement.

The WP10 offer includes five core services that help cities understand available solutions, prioritise actions, build internal capacity and access expert guidance. All services are available through the NetZeroCities Portal and are free to explore and use.

Knowledge Repository

The Knowledge Repository is the main library of the NetZeroCities Portal, gathering resources from across the project. As part of WP10, a structured set of thematic entries to help cities more easily explore technical solutions and understand where they fit in urban transitions has been contributed.

Such contributions include:

- A series of **overview articles** introducing each of the key **thematic areas** (e.g., stationary energy, energy generation, mobility, circular economy, etc.), offering framing insights and links to relevant solution factsheets.
- A curated set of **solution factsheets** organised under those thematic areas, covering a wide range of technical options and innovation pathways.

This structure enables cities to navigate by topic, even in the absence of that exact tagging, and quickly find actionable solutions that match their challenges.

- ❖ **Link: https://netzerocities.app/knowledge**
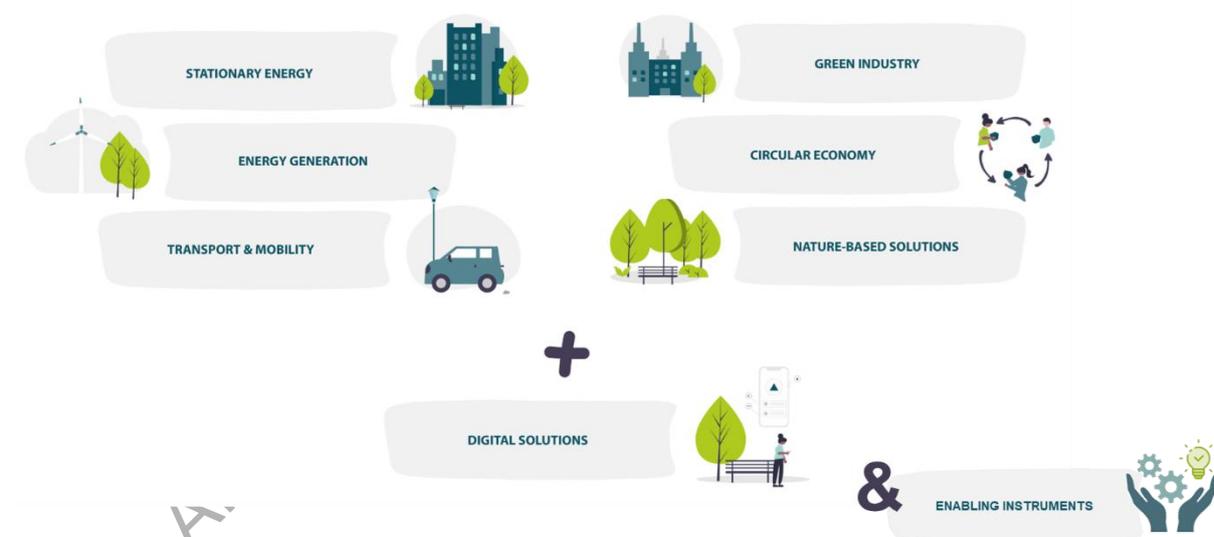
Figure 3: Thematic areas used to structure WP10 contributions to the Knowledge Repository

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Solution Bundles

The Solution Bundles tool presents groups of synergistic technical solutions that together address systemic challenges faced by cities. It allows users to visually explore how different solutions relate to one another and contribute to climate neutrality goals.

A new, more intuitive **3D interface** has been developed as part of WP10 to improve user navigation and engagement. Cities can use the tool to support strategic planning and the co-design of integrated action portfolios.

❖ **Link: https://netzerocities.app/solution-bundles**
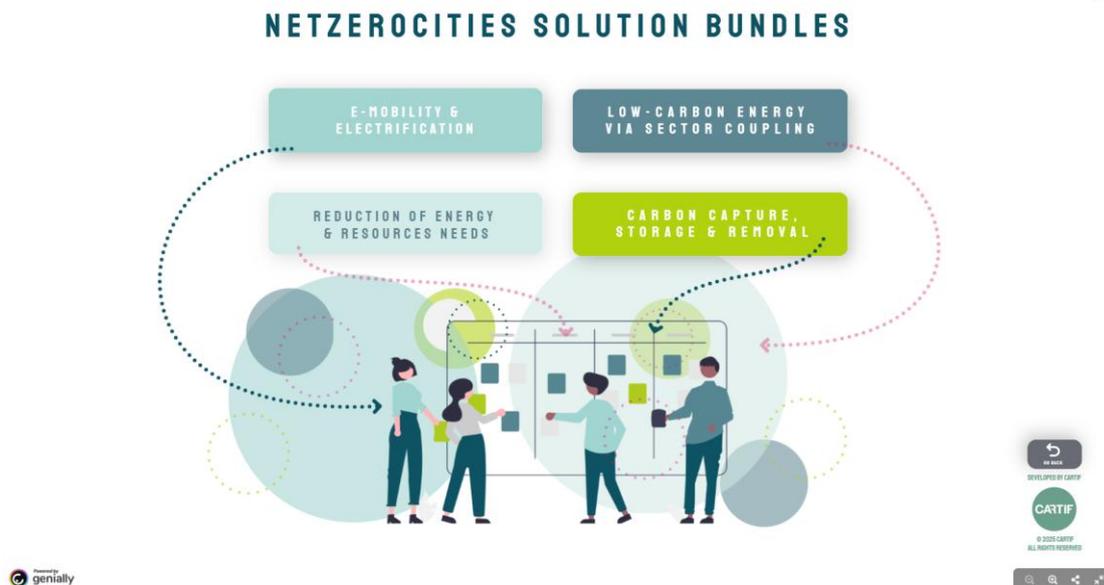
Figure 4: Screenshot of the Solution Bundles tool, showing the four systemic bundles available for city action planning

Solution Outliner

The Solution Outliner is a prioritisation support tool that assists cities in identifying relevant solutions based on their specific challenges, barriers and transition domains. By answering a short set of questions, users receive a customised set of recommended solutions tailored to their local context. The tool complements the Solution Bundles by providing a starting point for more targeted exploration. Developed as part of WP10, the Outliner supports cities in **navigating complexity and making confident early decisions**.

❖ **Link: https://netzerocities.app/solution-outliner**

Figure 5: Screenshot of the Solution Outliner tool, landing page

Learning Programme

The Learning Programme is a curated capacity-building programme designed to help cities formulate an integrated portfolio of actions using WP10 tools and services such as the Knowledge Repository, the Solution Bundles and the Solution Outliner. It is self-organised and self-paced and users are thus in the lead to run the Programme without the support of the NZC consortium. Throughout the five training modules, composed of self-study and group sessions, cities learn about the purpose, structure, and process of developing an integrated portfolio of actions. The flexibility of the Learning Programme allows individuals to focus on self-study or groups to engage in collaborative sessions.

- ❖ **Link: https://netzerocities.app/group-capabilitybuildingprogrammeexperimentingwithaportfolioofactions**

Demand-Driven Expertise

This service offers tailored technical support to Mission and Pilot cities seeking deeper guidance on specific themes, tools or planning needs. This work aims to respond to the cities' domain-specific questions in a focused manner and support them in overcoming the challenges they face. Through WP10, in-depth thematic expertise has been provided to cities in various formats: participation in meetings alongside City Advisors, contributions to capacity building through domain-specific peer-learning sessions, webinars and events, and direct support to the Pilot cities in collaboration with the NZC Pilot Cities programme team. Mission Cities can access this support by coordinating through their assigned City Advisor or by contacting the NZC helpdesk. While initially designed to assist Mission and Pilot Cities, the insights and learnings can inform ongoing work across the broader NZC community.

3 WP10 Services for climate-neutral cities: what's available to you

This section presents the five-core service developed in WP10 to support cities in designing, implementing, and strengthening their climate-neutrality pathways. Each service addresses a specific need: from exploring technical options to prioritising actions, building capacity and accessing expert guidance.

You'll find a short description of each tool, direct access links, visuals of the interfaces and practical tips to help you get started. Whether you are just beginning or refining your approach, these services are ready to support your next steps.

Knowledge Repository
Structured access to technical solution factsheets, grouped by thematic areas, with implementation insights.

Solution Bundles
Interactive tool for exploring how solutions work together in systemic groupings to address city challenges.

Solution Outliner
Guided tool that recommends relevant solutions based on your city's needs, barriers and transition areas.

Learning Programme
A self-organised and self-paced programme supporting cities to formulate an integrated portfolio of actions.

Demand-Driven Expertise
Tailored support through walkthroughs, advisory input and thematic guidance, coordinated via City Advisors.

Figure 6: Overview of the WP10 Toolbox: five services designed to help cities explore, prioritise, learn and act on their climate-neutrality pathways

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3.1 Knowledge Repository – access to technical solutions and real-world examples

What it offers

The Knowledge Repository is a central component of the NetZeroCities Portal, and provides cities with structured access to **technical solutions** and resources to support climate neutrality planning and implementation. It includes both project-wide content and a curated collection of **factsheets and thematic articles** contributed by WP10.

These materials are grouped into **thematic areas** and designed to support cities in identifying relevant solutions, understanding implementation needs, and **making informed decision**s across their portfolios.

How it functions (methodology & interface)

Each solution factsheet follows a structured, expandable format that goes beyond simple descriptions. The content includes:

- A brief overview of the solution and its field of applications, almost always accompanied by a visual element.
- **Co-benefits** it can generate (across themes like resilience, equity, biodiversity, health, economy, etc.).
- **Pre-conditions and enabling factors,** and common **constraints/barriers** to implementation.
- Potential **adverse impacts** and mitigation considerations.
- Relevant **indicators**, aligned with DNSH principles.
- **Implementation instruments** (technical, regulatory, financial).
- And real-world examples and references.

This design helps cities assess the technical fit, implementation complexity and systemic value of each solution in a consistent, decision-oriented way.

Figure 7: Screenshot of a solution factsheet showing key sections (co-benefits expanded)

The co-benefits (Figure 8) shown in each factsheet are based on a structured framework developed in WP10 to help cities evaluate systemic impacts.

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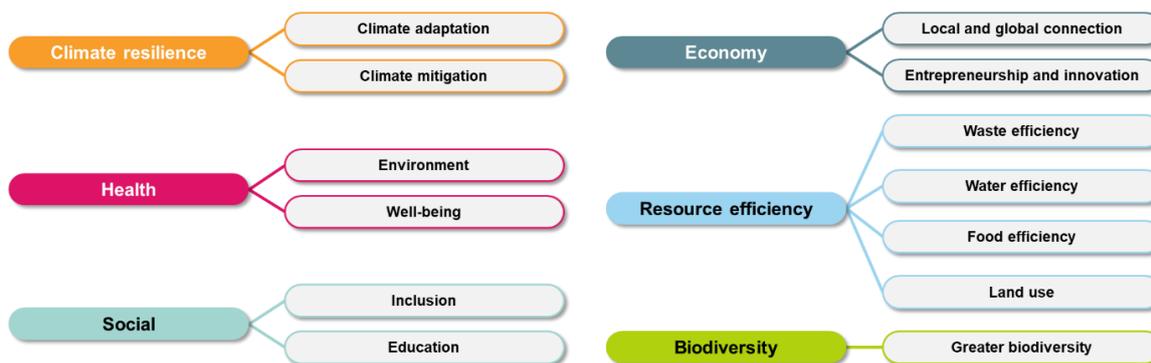
Figure 8: WP10 co-benefits framework used to classify solution impacts in the KR, helping cities identify broader outcomes

WP10 contribution

Within the Knowledge Repository, WP10 contributed to the following:

- Developed a harmonised **factsheet template** and **structured content approach**.
- Authored a series of **overview articles** to introduce and group solutions by thematic areas.
- Applied a **co-benefits framework** to guide internal curation.
- Tagged and uploaded **over 170 solutions**, helping bridge gaps where the platform taxonomy was still evolving.

This helped transform the repository from a static catalogue into a **design support environment** tailored to city needs.

How it evolved (feedback and updates)

The Knowledge Repository has undergone several improvements since its initial release, guided by city feedback and internal reviews:

- **Light maintenance actions**: systematic update of outdated links (e.g., replacing broken EU project links with permanent CORDIS or Horizon Results Booster sources) to ensure the continued reliability of referenced resources.
- **Preliminary analysis of Climate City Contract actions**: WP10 mapped the solutions most frequently included in cities' CCCs against the Knowledge Repository catalogue. This showed that a limited set of 'high-frequency' actions (such as waste reduction, replacement of equipment, building envelope retrofits, solar PV and e-mobility) are standard across many cities. These findings suggest logical priorities for future improvements and deeper support in future updates (see Figure 9).

Top 15 Topics by Number of Cities Involved
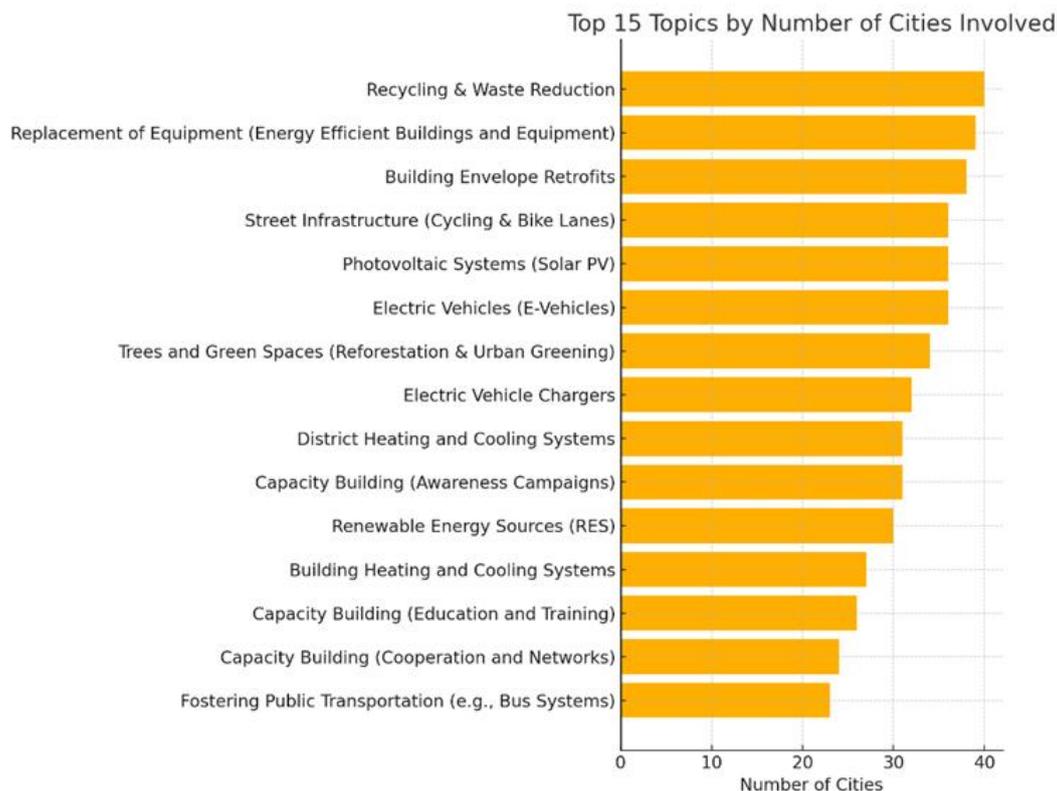
Figure 9: Most frequent solution areas in CCCs (number of cities)

- **Improved tagging and search**: to make the Repository easier to navigate, WP10 partners developed AI-based tagging models aligned with the consortium-wide taxonomy. These ensure accurate categorisation of resources, improve search and relevance, and enhance cross-tool consistency (linking to the Solution Outliner and Bundles).

- **Validation and future use**: the first AI-tagged version is currently in testing. After curation and validation by content owners, it will be integrated into the production environment, ensuring up-to-date, harmonised tags across all resources. Detailed information about this model performed for the overall Knowledge Repository improvement is on **Annex 3 Tag recommendation system in NetZeroCities**.

What value it brings

The Knowledge Repository provides cities with a **trusted, structured environment** to explore and compare solutions that directly support climate neutrality. Its value lies in:

- **Evidence-based decision support**: factsheets combine technical detail with co-benefits, barriers and real-world examples, allowing cities to weigh trade-offs and select fit-for-purpose solutions.

- **Systemic perspective**: the co-benefits framework helps cities understand broader impacts (on resilience, health, equity, biodiversity, etc.), ensuring that chosen solutions contribute to multiple goals.

- **Time and resource efficiency**: curated content and improved tagging make it easier to find relevant solutions quickly, avoiding duplication of effort and helping teams move from planning to action faster.

- **Integration with other WP10 tools**: the Repository acts as a foundation for systemic planning when combined with the Solution Bundles and Outliner, helping cities design coherent portfolios of action.

Together, these features make the Knowledge Repository not just a library, but a **practical support environment** that enhances cities' ability to plan, prioritise, and implement their climate transition strategies.

How cities can use it

Cities can make the most of the Knowledge Repository by following these simple steps (Figure 10):

1. **Access the KR** via the NZC Portal.
2. Start with a **thematic overview article** in the most relevant domain.
3. **Explore grouped solutions** and open the linked factsheets.
4. **Browse solution factsheets** for deeper details, including barriers, enablers and real-world examples.
5. Search using **filters or keywords** to find specific resources.
6. **Engage with content** by rating, commenting or sharing experiences.

For a full visual step-by-step walkthrough with screenshots, see **Annex 1.1 How to browse the Knowledge Repository**.
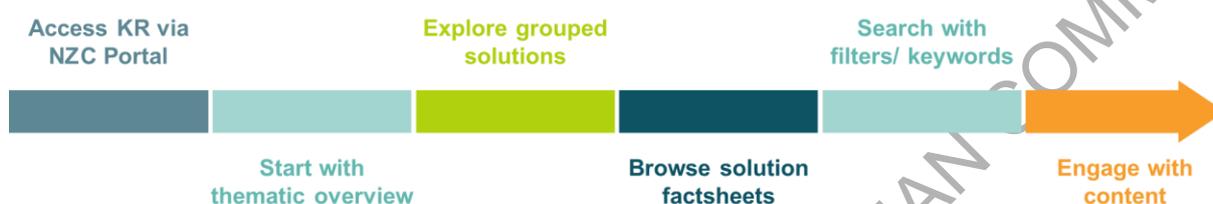
Figure 10: Key steps for navigating the Knowledge Repository

Where to find it

- https://netzerocities.app/knowledge

Explore WP10's thematic overview articles:

Box 1. Thematic overview articles within the KR that introduce grouped solutions

- **Stationary Energy (Buildings)**
- **Energy Generation**
- **Mobility and Transport**
- **Green Industry**
- **Circular Economy**
- **Nature-based Solutions and Carbon Sinks**
- **Digital Solutions**
- **Enabling Instruments**
- **Concepts that support climate neutrality city targets (combine several solutions together)**

A full list of all solution factsheets and grouped resources contributed under WP10 is available in **Annex 2 List of all factsheets and resources developed under WP10** of this document.

Example in action

Box 2. A city's first steps: using the Knowledge Repository to build a solution strategy

A mid-size city is preparing to update its building renovation strategy to align its Climate City Contract goals and address worsening summer heat stress. The technical team begins by exploring the "*Stationary Energy (Buildings)*" thematic overview article in the Knowledge Repository.

There, they find grouped solution factsheets relevant to building envelope improvement and passive cooling. They focus on "*Envelope insulation*", "*Passive design strategies*" and "*Green roofs*".

For each, they review barriers to implementation (e.g., cost, heritage constraints), access co-benefits like improved indoor comfort and energy savings, and check associated indicators linked to climate neutrality targets. They export key information to brief local policy-makers and begin shaping their retrofit programme using evidence from real-world cases.

3.2 Solution Bundles – systemic thinking through visual solution groupings

What it offers

The **Solution Bundles** tool helps cities move beyond isolated actions by showing how **climate solutions can be combined into integrated and systemic portfolios**. It offers a visual and interactive environment where users can explore **synergies between solutions**, understand how they reinforce each other, and see where they might be deployed across urban areas. The tool complements the Knowledge Repository (for technical detail) and the Solution Outliner (for prioritisation), acting as a bridge between strategic visioning and actionable portfolios.

The tool is grounded in the idea that cities operate within **interconnected systems**, where progress often depends on activating multiple levers in parallel (e.g., combining technology adoption with behavioural change, finance models or policy instruments). Bundles, therefore, show not only what to do, but how actions can **reinforce each other** to generate greater impact.

In its final version, the tool goes a step further by offering an **interactive 3D city environment** where users can (see Figure 11):

- Select from **four strategic solution bundles** (see previous Figure 4): Low-carbon energy via sector coupling, E-mobility & electrification, Reduction of energy and resource needs, and Carbon capture, storage & removal.

- Visualise where actions may unfold spatially within **key urban areas** (e.g., neighbourhoods, industrial zones, green corridors or port areas).

- Explore how solutions interact across the **WP10 thematic areas**, including stationary energy, energy generation, mobility and transport, nature-based solutions, circular economy, green industry, digital solutions, and enabling instruments.

- Access **contextualised solution descriptions** linked directly to the Knowledge Repository (factsheets).

Figure 11: Thematic Solution Bundles presentation in the tool

How it functions (methodology & interface)

The Solution Bundles tool structures climate solutions into systemic portfolios, allowing cities to explore how actions interact and reinforce each other. The tool operates through an intuitive 3D interface on the NetZeroCities Portal, guiding users from high-level thematic entry points to detailed solution views.

Its methodological backbone is the grouping of solutions into the four strategic bundles. Each bundle integrates solutions from the WP10 thematic areas and visualises them spatially across different urban zones.

Through the interface, users can:

- Enter via strategic bundles and review their rationale.
- Apply thematic filters to view relevant solutions across domains.
- Navigate a 3D city environment to see where solutions can be deployed.
- Zoom into neighbourhoods, industrial areas, port zones or green corridors.
- Click on icons to access technical details in the Knowledge Repository.

This structure provides a methodological bridge between systemic thinking and actionable urban planning, ensuring solutions are not seen in isolation but as part of interdependent portfolios.
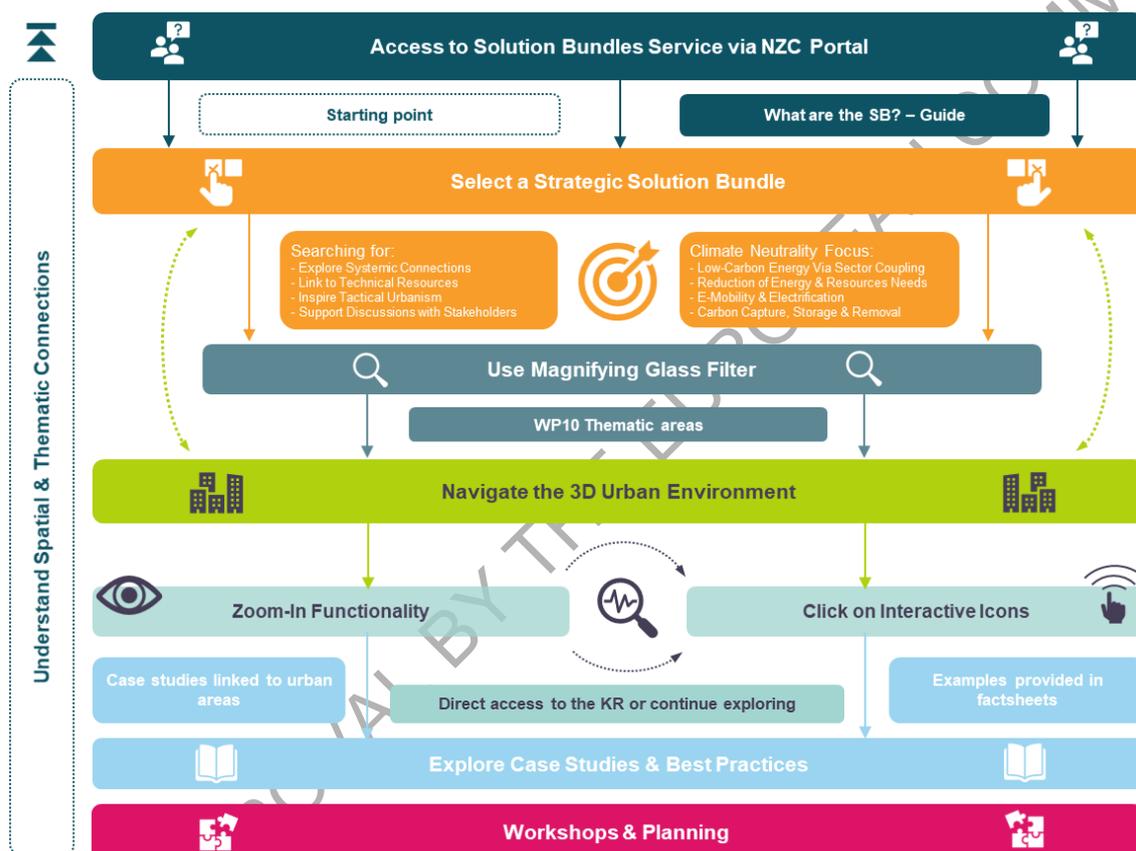
Figure 12: User flow of the Solution Bundles tool, from strategic entry to interactive exploration

How it evolved (feedback and updates)

The Bundles tool has significantly progressed since its early conceptual version. Originally presented in 2D, it now offers a fully interactive **3D city environment** with enhanced functionality and user experience.

Key updates include:

- Transition from 2D to **immersive 3D mapping** of solutions across urban zones.
- Addition of **multi-scale zooming**, allowing exploration from city-wide strategies to neighbourhood-level clusters.
- Introduction of the **magnifying glass filter**, enabling thematic exploration across WP10 domains.
- Integration of **case studies and best practices** from European cities, supporting practical application and tactical urbanism.

- Refinements in **onboarding and navigation** following the Covenant of Mayors Practitioner Consultation (July 2024).
- **Visual and usability improvements** for a more professional, user-friendly interface.

These improvements transformed the tool from a conceptual framework into a **practical planning aid**, helping cities design coherent, systemic and spatially grounded portfolios of climate actions.

Figure 13 illustrates one of the strategic solution bundles (Low-Carbon energy via sector coupling) as visualised in the 3D interface, showing how solution icons are mapped onto key urban areas and linked to thematic filters (selector at the bottom left magnifying glass).

Figure 13: Visualisation of a thematic bundle in the 3D interface, with solution icons mapped across strategic urban areas and thematic filters

What value it brings

The Solution Bundles tool gives cities a **practical, visual way to explore how climate actions can be combined into coherent portfolios and spatially deployed**. Its interactive format is particularly useful in the early phases of planning, when refining Climate City Contract actions, or for aligning stakeholders around shared priorities.

Cities can use the tool to (see Figure 14):

- **Identify relevant bundles** aligned with climate goals, challenge areas or thematic domains (e.g., energy transition, mobility, nature-based solutions).
- **Explore systemic connections** to understand how technical, social and policy levers interact across the city.
- **Support collaborative discussions** with departments or with stakeholders, using a shared visual reference.
- **Inform portfolio design** by mapping solutions to spatial areas or thematic clusters, shaping coherent intervention pathways.
- **Link to technical resources** in the Knowledge Repository for deeper analysis, co-benefits, funding and real-world examples.
- **Inspire tactical urbanism** through best practices that enable cities to test temporary interventions before scaling them up.

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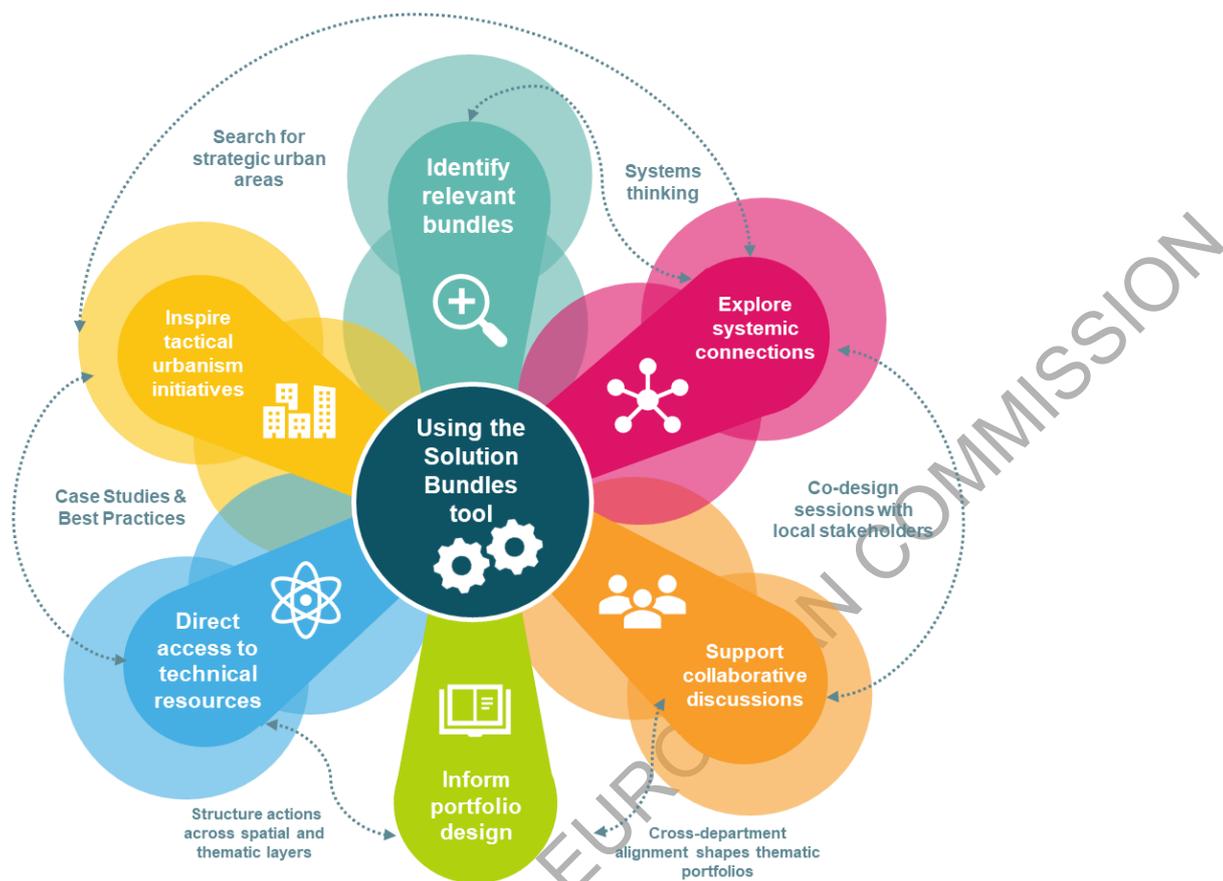
Figure 14: Applications of the Solution Bundles tool in city planning and collaboration

Whether used for **strategy refinement, cross-departmental alignment, or communication with local stakeholders**, the tool helps cities strengthen a systemic thinking and design actionable and future-proof portfolios.

How cities can use it

Cities can use the Solution Bundles tool by following a set of steps that guide them from strategic entry points into detailed exploration:

1. **Access the tool** via the NZC Portal (ACT section) and review the user guide and learning programme resources.
2. **Select a strategic bundle** that aligns with your city's objectives (e.g., Low-carbon energy via sector coupling, E-mobility & electrification).
3. Read the short introduction to understand the bundle's rationale and scope.
4. **Apply thematic filters** (magnifying glass) to explore bundle content through WP10 thematic areas such as stationary energy, mobility, circular economy or nature-based solutions.
5. **Navigate the 3D urban environment** to see how solutions are mapped across different urban areas (e.g., neighbourhoods, industrial zones, port areas, green corridors).
6. **Zoom in on priority areas** to examine clusters of interventions in more detail.
7. **Click on interactive icons** to access technical factsheets in the Knowledge Repository, including co-benefits, barriers and enablers.
8. **Review case studies and best practices** embedded in the tool to learn how other cities have implemented similar interventions.
9. **Use outputs in planning workshops** to support discussions with municipal departments or stakeholders, and to refine your Climate City Contract actions.

For a full visual step-by-step walkthrough with screenshots, see **Annex 1.2 How to use the Solution Bundles tool**.
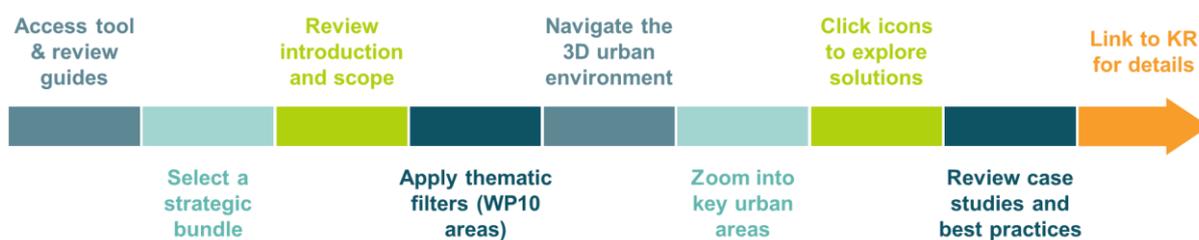
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Figure 15: Key steps to explore the Solution Bundles tool

Where to find it

The Solution Bundles tool is part of the **ACT** section in the NetZeroCities Portal, where all available tools are showcased.

- Access the Solution Bundles: https://netzerocities.app/solution-bundles

The tool is freely accessible online and requires no login.

Example in action

Box 3. A city's first steps: using the Solution Bundles Services for integrated neighbourhood planning

A medium-sized city is working on updating its Climate City Contract (CCC) and wants to cut emissions while improving residents' quality of life. During a planning workshop, the city's technical team opens the Solution Bundles tool to explore how different climate actions might come together in practical ways.

They start by selecting the Low-Carbon Energy via Sector Coupling bundle and zoom into a dense residential neighbourhood. Here, they identify options like renovating district heating networks (DH&CN) from 1G and 2G to more efficient systems, integrating waste heat recovery from nearby industries, and introducing microgrids to manage local energy flows. They realise that modernising the heating network could not only reduce CO_2 emissions but also lower household energy bills.

Switching to the Reduction of Energy & Resources Needs bundle, they examine how building envelope upgrades, passive design measures, and low-carbon construction materials could be combined for a planned refurbishment of social housing blocks. The team sees that better insulation and passive cooling strategies would improve indoor comfort, especially during summer heatwaves. Exploring further in the Carbon Capture, Storage & Removal bundle, they see opportunities to transform rooftops and building façades into green roofs and vertical green walls, helping capture carbon, reduce urban heat, and improve biodiversity.

However, they quickly realise that the tool doesn't only apply to neighbourhoods in isolation. They use the 3D interface to view connections with other urban areas. For example, they explore how an industrial zone adjacent to the neighbourhood could supply waste heat to the district heating network, how port areas could host solar installations contributing electricity to the grid, or how a green corridor could link the neighbourhood to city parks, improving air flow and promoting active mobility.

Inspired, the city team sketches out a tactical urbanism pilot: they plan to test green façades on one block, and host community workshops to co-design building renovations. Their goal is to combine solutions from different bundles into an integrated action plan that reduces emissions, cuts energy costs, and creates a greener, healthier urban environment.

3.3 Solution Outliner – Prioritising actions based on your city's needs

What it offers

The **Solution Outliner** is a strategic planning and decision-support tool developed by NetZeroCities to assist European cities in their journey toward climate neutrality. It is designed to help cities navigate the complexity of urban transformation by offering a structured approach to identifying, evaluating, and prioritising climate solutions.

The tool provides:

- **A curated database of climate neutrality solutions**, covering a wide range of sectors such as mobility, energy, buildings, waste, and nature-based solutions.
- **A framework for contextual analysis**, allowing cities to assess solutions based on their local conditions, including governance structures, socio-economic factors, and existing infrastructure.
- **Prioritisation guidance**, helping cities focus on interventions that are not only technically feasible but also socially inclusive, economically viable, and environmentally impactful.
- **Support for systemic thinking**, encouraging cities to consider how different solutions interact and contribute to broader urban transformation goals.

By offering these capabilities, the Solution Outliner empowers cities to move from broad climate ambitions to actionable strategies tailored to their unique context.

How it functions (methodology & interface)

The Solution Outliner operates through a structured, step-by-step methodology that guides cities in building a coherent portfolio of climate actions. The process typically involves:

1. **Contextual input collection:** cities begin by providing detailed information about their local context, including:
   - Existing climate targets and ambitions.
   - Key barriers and enablers (e.g., political will, funding availability, public support).
   - Desired co-benefits (e.g., improved air quality, job creation, social equity).
   - Systemic challenges and opportunities.
2. **Solution matching and assessment:** based on the input, the tool matches the city's profile with relevant solutions from its database. Each solution is assessed across multiple dimensions:
3. **Prioritisation and portfolio building:** the tool then helps cities prioritise solutions by ranking them according to their strategic fit and potential impact. Cities can explore different combinations of solutions to build a portfolio that aligns with their climate neutrality roadmap.
4. **Iterative refinement:** cities can revisit and refine their inputs and selections as new data becomes available or as their strategic priorities evolve. This makes the tool adaptable and responsive to changing conditions.
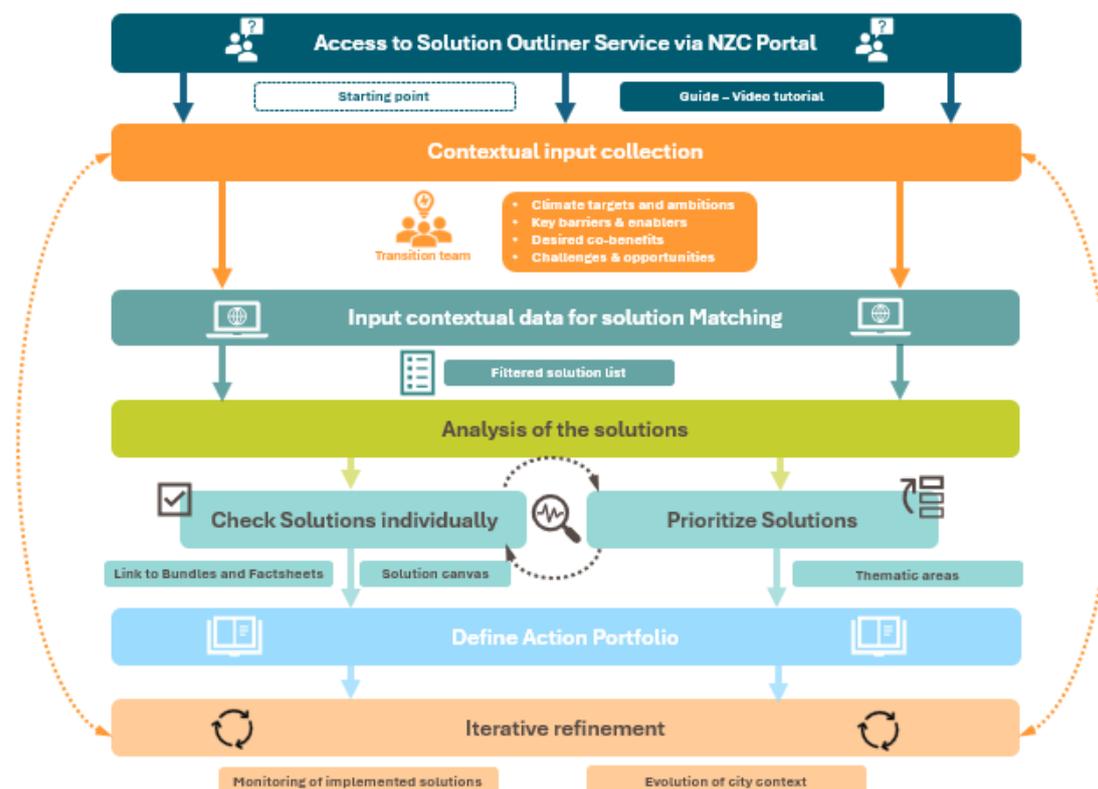
Figure 16: User flow of the Solution Outliner tool, from strategic entry to interactive exploration

How it evolved (feedback and updates)

Since its launch on the NZC Portal in 2024, the Solution Outliner (beta version, accessible in the portal) has remained largely stable, with efforts focused on evaluating its value to cities and gathering structured feedback to guide the final version integrated in the portal. An external consultancy reviewed in 2025, combining desk research, portal benchmarking and interviews with seven European cities (Barcelona, Espoo, Ludwigsburg, Milano, Potsdam, Prague and Zurich).

Key insights from the evaluation include:

- **Positive highlights**: Cities appreciate the tool as a structured entry point to the NZC solutions database. It helps them visualise available options, reflect internally on what may fit their context, and serves as an educational and communication aid, particularly for smaller or less experienced cities starting their climate planning journeys.

- **Identified needs**: Cities highlighted the importance of receiving fewer but more relevant prioritised solutions, tailored to their local context. They also called for more detailed technical and quantitative information (e.g., on feasibility, costs, and impacts), better usability (more precise terms, more straightforward navigation, ability to save/export results), and options for collaborative use.

- **Integration opportunities**: Feedback also highlighted the need for stronger connections between the Outliner and the other WP10 tools (Knowledge Repository, Bundles, Learning Programme), as well as alignment with the broader NZC Portal ecosystem.

The next development phase will therefore focus on implementing the **quality of recommendations**, enriching **content depth**, and enhancing **user experience** and integration with other services. This integration will also be needed for the rest of the tools of the NZC ecosystem. The tagging process carried on for the Knowledge Repository will be a good starting point to create and reinforce the links among all the tools.

What value it brings

The Solution Outliner supports cities in **prioritising climate solutions** from the Knowledge Repository, helping them move from a long list of options to a focused set of interventions tailored to their context. Its structured approach makes it easier for municipal teams to navigate complexity, compare options, and identify pathways that are both feasible and impactful.

The tool brings value by:

- **Guiding decision-making**: enabling cities to filter solutions according to ambition level, barriers, enablers, and potential co-benefits.
- **Saving time and resources**: reducing the effort required to identify relevant solutions from an extensive catalogue.
- **Supporting early-stage planning**: particularly useful for cities beginning their climate neutrality journey, where internal expertise may be limited.
- **Facilitating communication**: providing a clear, visual way to discuss solutions with colleagues, stakeholders, and political leaders.
- **Laying the groundwork for integration**: serving as a bridge to other WP10 tools, especially the Knowledge Repository for technical details and the Bundles tool for systemic portfolios.

Together, these features make the Outliner a **practical entry point for cities of different sizes and capacities**, strengthening their ability to prioritise solutions and design coherent, context-sensitive action plans.

What cities can achieve with the Outliner. Beyond generating prioritised solutions, cities can use the Outliner to:

- **Identify relevant solutions** tailored to local priorities and socio-economic conditions.
- **Prioritise effectively** by focusing on high-impact interventions with clear co-benefits.
- **Develop systemic approaches** by exploring how solutions interact.
- **Create coherent portfolios** of climate actions aligned with CCCs.
- **Filter and consult solutions** to support evidence-based decision-making.
- **Enhance climate planning** by integrating both qualitative and quantitative data.
- **Collaborate and learn from peers** as future versions integrate sharing functions.
- **Monitor and evaluate progress** by revisiting and updating priorities over time.

How cities can use it

The Solution Outliner is a valuable online resource for cities to discover and prioritise effective climate solutions at every stage of their climate neutrality journey. Through its interactive interface, cities can efficiently navigate the complexities of climate action planning, identify synergies, and develop a tailored portfolio of climate solutions that meet their unique needs and goals. This versatile tool can be utilised during the design process to identify and prioritise relevant solutions, during implementation to monitor progress and evaluate effectiveness, and later to inform and refine future planning and new interventions, ensuring that climate action plans remain effective, up-to-date, and aligned with evolving needs and priorities.

1. **Review your city's context** before starting, and involve the Transition Team to agree on your city's context conditions.
2. **Access the tool** via the NZC Portal (ACT section) and review the user guide and video.
3. Read the instructions included in the tool to understand the Solution Outliner's rationale and scope.
4. **Select your ambition and context conditions** (defined in Step 1) in the Selection screen to shape how the tool filters the solutions.
5. **Check filtered solutions** to examine how they can be implemented and how the solutions can interact by exploring the technical factsheet in the Knowledge repository and their ambition/context connections.
6. **Generate prioritised solutions** to facilitate the selection of those with a higher impact according to the city profile.

7. **Use outputs in the planning process** to support discussions with the municipal department or stakeholders, and to refine your Climate City Contract actions.
8. It is possible to re-run the tool with different inputs to compare scenarios.

For a full visual step-by-step walkthrough with screenshots, see **Annex 1.3 How to use the Solution Outliner.**
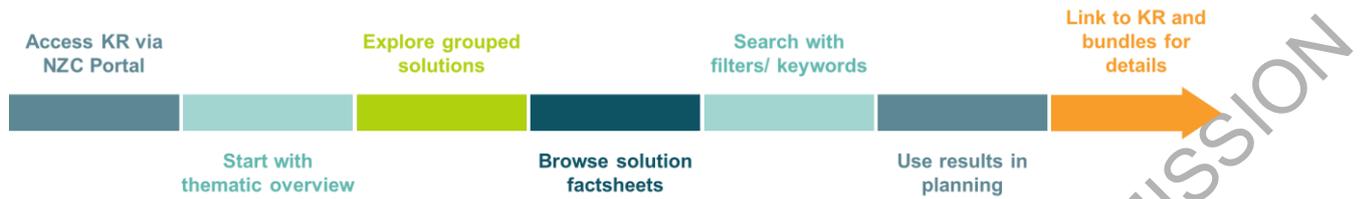
Figure 17: Key steps to explore the Solution Outliner tool

Where to find it

The **Solution Outliner** tool is part of the **ACT** section in the NetZeroCities Portal, where all available tools are showcased.

- Access the Solution Outliner: https://netzerocities.app/solution-outliner

The tool is freely accessible online and requires no login.

Example in action

Box 4. A city's Transition team working on finding technical solutions to reduce their GHG emissions with special focus on mobility

The Urban City transition team is working in their Climate City Contract. The team has already defined a baseline GHG inventory, which shows that mobility is a key target domain to tackle city neutrality. Moreover, at the national level, there is a new Urban Vehicle Access Act that only cities to implement restrictions on private mobility, such as the Low Emission Zones.

The team needs to look for specific solutions to start working on a portfolio of actions to include specific mobility measures in the Action Plan.

The team decides to use the Solution Outliner, so they start by discussing in a co-creation session which are the elements that define their actual context. They already know that mobility, and more specifically, Low Emission Zones is key, but to be more accurate in their searching, they start identifying their contextual conditions for, and they collectively select those that are more relevant:

For the team, a Low Emission Zone should be complemented with Accessibility and Mixed Uses measures; for that, in the Ambition dropdown menu, they select those elements. During the discussion, the representatives from the City Innovation department suggested to include also the Mobility Hub category as an innovation solution that has been included in a research project they are conducting.

With these four elements (Low Emission zones, accessibility, Mixed Uses and Mobility Hubs) the Transition Team starts discussing the co-benefits that those topics bring.

All agree on the clear linkages to climate resilience, such as the reduction of energy consumption and the consequent reduction of greenhouse gases, They also discuss the economic co benefits concerning the improvement of the local and proximity economy when the commercial areas become more accessible and liveable, as well as those effects linked to health due the air quality improvements.

Concerning the barriers, the whole Urban City transition team agree unanimously on selecting all the financial barriers. In contrast, they discuss intensively around the enablers, coming to an end by selecting the political and Regulatory ones and only one relational, such as the involvement of urban governments.

With the selection of these contextual criteria compared to the total Solutions compiled in the Knowledge Repository the tool offers a total of 73 prioritize Solutions such as:

- 15 minutes city

- Parking management, smart parking
- Sharing micro-mobility
- Mobility data strategy

Then the Transition team processes to check the prioritisation made for that they look at the prioritization checking scree in which the list of solutions, the graph with the top 20 solutions and a second filter option are shown.

The team decides to use the second filter, looking for synergy action areas such as digitalisation or adaptation. So, they first select nature-based solutions, then from the 73 solutions, the tool brings 12.

Finally, the team clicks on the Solution Check button to analyse some of the solutions prioritised one by one. Thanks to the canvas's information they continue working on their action plan definition.

3.4 Learning Programme – Formulating an integrated portfolio of actions

What it offers

The Learning Programme (LP) offers policy makers of different city departments, who work on climate actions (urban planning, housing, mobility, energy, economy, waste, etc.), a structured process aimed at formulating an integrated portfolio of actions to reach climate neutrality. By using tools and services on the NZC portal, such as the Knowledge Repository, the Solution Bundles and the Solution Outliner, cities can explore various technical solutions the Portal offers and test alternative scenarios to develop an integrated portfolio of actions. Moreover, the programme makes cities more familiar with the different ways of how to look up information and knowledge on the Portal, based on their specific cities' ambitions, barriers and enablers.

How it functions (methodology & interface)

The Learning Programme is self-organised and self-paced, and users are thus in the lead to run the Programme without the support of the NZC consortium. Throughout the five training modules, composed of self-study and group sessions, the programme makes policy makers more familiar with the different ways on how to look up information and knowledge on the Portal, based on their specific cities' ambitions, barriers and enablers. The flexibility of the learning programme allows individuals to focus on self-study or groups to engage in collaborative sessions. The Learning Plan guides participants through the Learning Programme, see Figure 18 for the table of contents.

Table of contents

Figure 18: Table of contents of the Learning Plan

As shown below, each module has clear goals, and the knowledge input of the module generates concrete results. These results are the starting point for the following module. Each module can use different training approaches to activate the participants' learning trajectory and support them in gaining invaluable insights, practical knowledge, and actionable strategies to navigate the complexities of sustainable urban development, while creating a space for learning among peers. These approaches (e.g., self-study, P2P networking, interactive workshops, thematic exploration sessions or collaborative forums) foster an environment open to continuous learning, innovation and reflection.

The goals for each module are shortly introduced:

- **Module 1 – Kick off**

  In this first module, participants get familiar with the topic and goals and each participant can list their expected (personal) learning goals, get acquainted with the other users, and divide roles and responsibilities among participants.

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- **Module 2 – Introduction of the terms**

  The goals of this module are an introduction to and understanding of the terms: actions, co-benefits, barriers and enablers (using case studies as inspiration of integrated portfolios). As an exercise, the group defines their (hypothetical) city's actions, co-benefits, barriers and enablers.

- **Module 3 – Exploration of NZC tools**

  In this module, the participants get familiar with (introduction and exercise on how to use them) with the Knowledge Repository, Solutions Bundles and Solution Outliner. As a result, the group has a short list of solutions, based on their (hypothetical) city's actions, co-benefits, barriers and enablers.

- **Module 4 – Portfolio Integration**

  The fourth module is where the integration takes place. The main goal is to guide participants on how to optimally utilise the Solution Outliner, Solution Bundles, and the Knowledge Repository to develop robust and integrated packages of solutions, based on the group's short list of solutions. Various ways of integrating the solutions (e.g. based on actions, barriers or enablers) are discussed among the group.

- **Module 5 – Reflections**

  The main goal of the last module of the LP is to facilitate a reflective space for the team to assess the outcomes of their LP, as well as to provide them with a platform for sharing experiences, lessons learned, and attaining continuous improvement. The results of these reflections can feed into an update of the LP structure, so it can better serve future participants. Via the NZC public group of this LP, the shared learnings and reflections can also be exchanged with other (future) groups using the LP.

How it evolved (feedback and updates)

The Learning Programme builds on the work that was done in NZC Deliverable 3.2: Capacity Building Framework. As described in NZC D3.2: *"A Learning Journey* (Current term is Learning Programme) *aims for continuous development and application of Portal users' skills and knowledge by providing a collaborative (online or offline) space for learning, taking place in parallel to working on climate neutrality action or goals, and by connecting the various capacity building components ((interactive) tools and methods, use cases, solution factsheets, P2P groups) of the portal in the most useful manner for the specific and contextual needs of the user(s)"*.

In D10.5, this learning programme was titled *Capacity Building (Learning Journey)*. Moreover, as the WP10 tools and services have further developed, the Learning Programme was also adjusted accordingly. This to offer the most updated version of what the NZC Portal has to offer. Since WP10 tools and services will continue being updated and improved, the Learning Programme will also be updated regularly.

The content of the modules introduced in D10.5 has been thoroughly revised, while maintaining the core objective: to support cities in formulating an integrated portfolio of actions using NZC tools. Specifically, the previous Modules 2 to 4 have been restructured as follows:

- Module 2 now focuses on the introduction of key terms,
- Module 3 explores the NZC tools in depth, and
- Module 4 is dedicated to portfolio integration.

Introducing a dedicated module for terminology was essential, as many of these terms recur across the various NZC tools. Familiarising participants with this vocabulary early in the programme ensures a smoother learning experience. Meanwhile, the original Module 4, which focused on tracking and monitoring, was deemed less relevant in the context of this short-term programme. Since tracking and monitoring are primarily long-term activities, they do not directly contribute to the immediate goal of portfolio integration for cities.

In addition, the learning programme has been enriched with new case studies and factsheets added to the Knowledge Repository over the years. These practical examples allow cities to learn from real-world experiences and best practices.

Finally, the entire programme has been adapted to be more inclusive of mission-oriented cities, with a reduced emphasis on the Climate City Contract (CCC) action plan.

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What value it brings

The Learning Programme empowers city policymakers to effectively navigate the journey toward climate neutrality by offering three core benefits. First, it enables participants to **get to know and confidently use the tools and services available on the NZC Portal**, such as the Knowledge Repository, the Solution Bundles, and the Solution Outliner, helping them explore technical solutions and test scenarios tailored to their city's context. Second, it fosters the ability to **collaborate across departments and with external stakeholders**, building a shared understanding and coordinated approach to achieve a good action plan. Third, it guides cities in **setting up an integrated portfolio of actions**, ensuring that climate strategies are not only technically sound but also aligned across various sectors like mobility, housing, energy, and economy. This holistic and hands-on learning process strengthens cities' capacity to design impactful, inclusive, and feasible pathways to climate neutrality.

How cities can use it

The participants can find all the self-study and group training material in the NZC group NetZeroCities. By clicking on the *Join* button, participants can access all training materials (tab *files*) and updates from previous groups and are able to post their questions or learnings in the group's feed.

Figure 19: Screenshot of Learning Programme group on the NZC portal

- The **online Portal group page** for this LP guides the participant to the Learning Plan, which explains to the participants how to use the learning material of the five modules.

- In **Module 3, Exploration of NZC tools,** the Knowledge Repository and its technical factsheets, and real-world case studies, the Solution Bundles and the Solution Outliner are introduced.

- By means of several individual and group exercises, the participants can practice using these NZC tools and services based on the goals they have.

- During several group exchange moments, participants can share the practical insights they have gained and translate these into actionable strategies for integrating technical solutions into their urban landscapes.

By facilitating knowledge input and exchange, skill-building, and collaborative problem-solving, our service empowers cities to embark on a transformative journey towards climate neutrality.

Where to find it

The Learning Programme is part of the **CONNECT** section in the NetZeroCities Portal, to which all the groups belong. The group page of this LP is to be found here: *Formulating an integrated portfolio of actions, using NZC tools*

In the future, the LP will also be added to the Tools page (under **ACT** section in the portal).

Example in action

Box 5. A city's first steps: getting started with the Learning programme to learn about an integrated approach for their portfolio of actions.

A Mission city is preparing to take further steps after the initial formulation of its Action plan, according to its Climate City Contract goals. The plan is currently rather broad, lacking coherence in terms of which actions are interlinked and can be considered together to better address the various ambitions. The transition team begins by going more in depth to identify its current state of climate action, looking deeper into its enablers and barriers, which can help them to set priorities and make a more concrete planning.

At this stage, they start the Learning programme, to make use of the portal tools, which can inform them about different potential solutions for their city and recommend a short list according to its needs, while it offers inspiration for creating an integrated portfolio of actions.

During the first, the kick-off module, and the self-study part, they get the opportunity to learn what an integrated portfolio of actions is and why it is useful for their city. They get to watch NZC Co-create a Portfolio Webinar, which provides a basis for cities' teams to understand what a portfolio approach is and clarify the vocabulary used. Furthermore, the video shows some inspirational examples of experts and Mission cities on how they planned their work for the co-creation of their portfolio: who to engage, what activities to prepare for, what needs to be available to start the process. At the end, they are asked to write down their main insights from the video, which examples presented they could use in their city and which examples presented wouldn't work in their city (and why not).

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3.5 Demand-driven expertise – customised support for Mission and Pilot cities

Demand-driven domain-expertise for mission cities

Partners with technical expertise have supported NZC City Advisors to find answers to cities' domain-specific questions, based on their needs. Depending on the demand, the scale and the nature of the question that cities have asked, experts have collected case examples from other cities and projects to share best practice examples and references about technologies and solutions to reduce emissions in different thematic sectors. For example, an energy expert from VTT supported CA to find relevant examples from other cities' strategies on how they are planning to phase out incineration-based district heating production.

On other occasions, experts have supported City Advisors by helping them better understand the specific challenges their cities are facing. This includes, among others, clarifying the terminology, explaining relevant phenomena regarding NZC, or providing insights into technical systems and their enabling conditions. Practically, experts have also advised CAs on what kinds of questions to ask city representatives in order to formulate better-targeted support requests. As an example, a VTT expert suggested that the CA working with Glasgow asks questions such as: What is possible? What is innovative? Where should the focus be? – to help shape a more specific and effective city support request.

If needed, technical experts from WP10 have also, on some occasions, participated in meetings with cities, together with the City Advisors. As an example, VTT experts have joined discussions with City Advisors about energy communities with Gabrovo, and sustainable energy transition planning with Sofia.

Domain-specific capacity building events and activities

Secondly, the domain-specific experts have organised and contributed to NZC capacity building events, among others in the Cities Mission conferences. In 2024, energy experts of NZC joined forces with Positive Energy District projects and held a joint peer-learning workshop on positive energy district solutions. In the next year, 2025, experts organised a peer-to-peer workshop for cities' energy experts at the Cities Mission conference about speeding up the energy transition. Here, NZC energy experts from VTT, CARTIF, Tecnalia, TNO, UPM and LGI, developed a curated selection of interesting energy innovations from cities' pilot projects and invited speakers from these cities to share their work.

Figure 20. Peer-to-peer Energy transition workshop for cities' energy experts in Cities Mission Conference, May 2025. (pictures: Mari Hukkalainen, VTT)

VTT's mobility experts have also supported the organisation of policy innovation labs, hosting one for Finnish cities about sustainable mobility transition and congested urban space in January 2025. Technical experts supported the group discussions with their expertise.

Figure 21. Policy innovation lab with Finnish cities about mobility transitions in Espoo, Finland, 01/2025

Technical experts were also supporting the planning and implementation of the NZC summer school in Milan in June 2025 (https://netzerocities.eu/2025/06/17/6th-netzerocities-seasonal-school-speeding-up-the-energy-systems-transition-to-climate-neutrality/). This was the first seasonal school with a specific domain focus on energy, namely "Speeding up the energy systems transition to climate neutrality". The NZC energy experts, mostly from VTT and C-KIC, helped to scope and plan the summer school sessions to provide NZC methodology, tools and approaches for how the city can better lead the energy transition at the district level. The sessions included:

- **Portfolio Mapping for District-Level Transition**: tools for strategising energy interventions.
- **Collaborative Stakeholder Engagement**: partnerships for successful energy transitions.
- **Integrated Monitoring, Evaluation & Learning**: developing robust frameworks to track progress and adapt strategies.
- **Financing Pathways for System Transformation**: exploring innovative funding mechanisms to drive change.
- **Smart Grids & Renewable Electricity Procurement**: understanding the infrastructure and sourcing for a greener energy future.
- **Governance & Transition Team Models**: organisational structures for climate action.
- **Policy Instruments for Decarbonised Networks**: navigating the regulatory landscape to support sustainable energy.
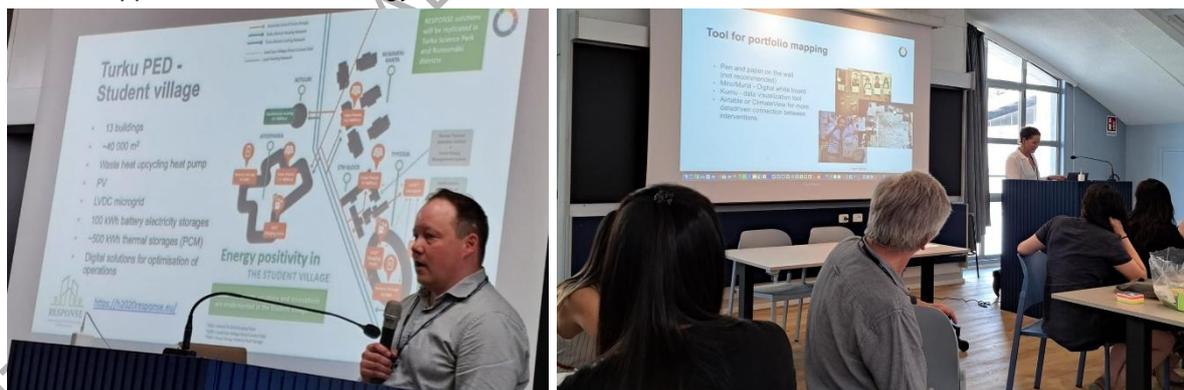
Figure 22. Pictures from the Energy focused NZC Summer School in Milan, June 2025 (VTT)

Customised support for pilot cities

Technical experts have supported pilot cities with small efforts, based on the demand of the cities. Experts have been supporting City Advisors on a demand basis, e.g. by joining some of the meetings with the Pilot Cities when discussion topics have been highly technical (e.g., for district heating demand response and energy flexibility pilot project's meetings with NZC City Advisor with the cities of Helsinki and Lappeenranta).
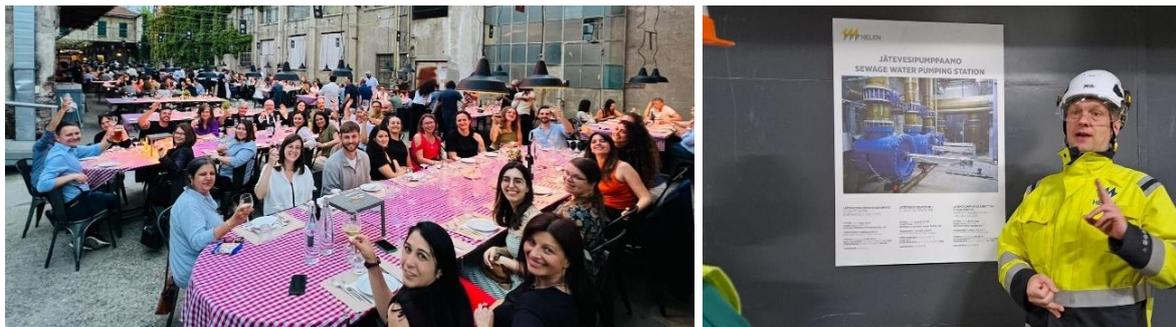
Figure 23. Pilot city project twinning site visit in a waste- energy-from waste water recovery plant in Helsinki, June 2025 (VTT)

Additionally, technical experts have joined some NZC Pilot programme events (e.g. ECT bootcamp in January 2025 for the pilot cities' kick-off event), where Pilot Cities could reserve time slots to have 1-on-1 discussions with technical experts. In this event, experts also helped to facilitate group discussions aimed at addressing and guiding cities to solve their challenges, e.g. on how to monitor and evaluate their pilot project.

Technical experts have also volunteered in "NZC expert support office hours", where the cities have been provided an option to reserve a 1-on-1 discussion time with them, to discuss about their specific issues and needs (between June-September 2025).

Figure 24. ECT (Enabling City Transitions) Bootcamp for pilot cities, January 2025

Technical expertise needed at other NZC WPs

In addition to direct city-phasing domain-specific support, the WP10 experts have also helped internally other NZC WPs in domain-specific questions with quick and focused activities. As one of the latest examples of this kind of work, in August 2025, experts have been requested to review the technical tags used across Notion Databases, supporting the creation of a professional and coherent data management approach. Some of the technical experts have volunteered to act as "thematic champions", supporting NZC network partnership team to improve and deepen the collaboration between NZC programme and other relevant projects, as well as to disseminate NZC knowledge portal and its services and how to utilise them.

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4 When to use what: making the most of the WP10 services across the climate transition

The **Climate Transition Map** serves as a shared reference for cities to navigate the complex and iterative process of achieving climate neutrality. It outlines key transformation phases, from building a mandate to understanding the system, co-creating interventions, taking action, learning and eventually embedding the change.

The five WP10 services were intentionally developed to **support cities across these phases**. Each tool offers value at different points in the transition, and together, they form an **integrated, modular support system.** This allows cities to move from challenge identification to implementation and learning in a flexible and context-specific way.

To help visualise this, Figure 25 maps each WP10 service onto the phases of the Climate Transition Map. This clarifies *when* each tool is most useful and highlights *how* they complement one another.

Explore the interactive Climate Transition Map at: https://netzerocities.app/ClimateTransitionMap.
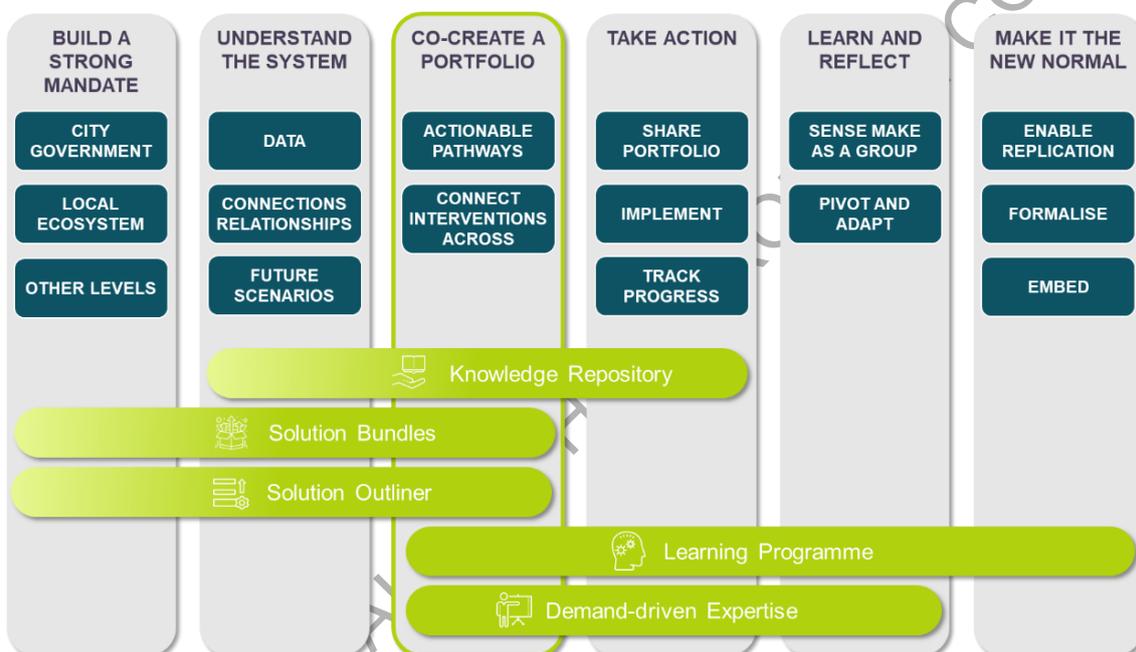
Figure 25: WP10 services mapped across the Climate Transition Map. Each tool supports key phases in the city transformation process and offers a route into action and impact

Where each tool adds value

- The **Knowledge Repository** appears under *Understand the system*, *Co-create a portfolio* and *Take action*. It offers deep insights into individual solutions, including enablers, impacts and implementation examples, making it useful across both planning and execution stages.

- The **Solution Bundles** tool spans *Build a strong mandate, Understand the system* and *Co-create a portfolio*. It encourages systemic thinking by showing how multiple solutions can work together in a cohesive and integrated portfolio.

- The **Solution Outliner** also contributes to the first three phases. It helps cities structure their thinking, define priorities and narrow down their options based on local levers and needs.

- The **Learning Programmes** present from *Co-create a portfolio* through *Make it the new normal*. These structured learning activities help city teams build the knowledge, capabilities and governance structures needed for long-term transformation.

- The **Demand-Driven Expertise** provides tailored support during *Co-create a portfolio, Take action* and *Learn & reflect*. It helps cities overcome challenges, refine solutions and receive context-specific advice as they move forward.

Using the toolbox efficiently

Each WP10 tool has a distinct purpose and entry point, but they are designed to be:

- **Interoperable**: usable in combination for deeper impact
- **Intuitive**: easy to access and apply regardless of city size or capacity
- **Accessible**: freely available via the NetZeroCities Portal

Cities can use the tools:

- **Sequentially**: following a progression from planning to implementation
- **In parallel**: across teams or departments, tackling different aspects
- **Selectively**: based on specific needs, priorities or challenges.

Annex 1 provides direct access links and practical mini-tutorials to help cities get started.

Combining tools for greater impact

Cities are encouraged to **combine WP10 services** for strategic value and greater coherence. For example (see also Figure 26):

- Use the **Solution Outliner** to define a key priority.
- Explore systemic combinations through the **Solution Bundles**.
- Engage in the **Learning Programme** to build team capacity and understand how to operationalise these tools and approaches.
- Dive deeper into **technical details** via the **Knowledge Repository**.
- Leverage **Demand-Driven Expertise** for tailored advice as challenges arise.

These tools are not fixed to a rigid sequence. Their strength lies in helping cities work **iteratively and strategically**, using the right resource at the right time based on evolving needs.

Figure 26: Suggested use pathway of WP10 services. Illustrates how cities can move from identifying a challenge to planning, preparing and taking action, supported by the right tools and learning resources

5 Conclusion

The suite of services developed under WP10 stands as a concrete contribution to cities' climate-neutrality pathways. From the Knowledge Repository to the Solution Bundles, the Outliner, the Learning Programme and the demand-driven expertise, these tools have been designed not only *for* cities, but *with* them. The process has ensured that solutions are practical, adaptable and rooted in the real challenges and opportunities faced by European municipalities.

This deliverable has sought to make these services accessible and actionable. Yet, their value will only be realised through active use: by cities exploring the resources, engaging with the tools, adapting them to local contexts and accelerating their programmes to transformation.

The message is therefore simple: the tools are here, ready to be used. We invite you to take them further: to **explore, engage, adapt and accelerate your city's programme**. Together, these steps can help cities move faster and more confidently towards a just, inclusive and climate-neutral future.

Annex 1.   Mini-tutorials

This annex includes short, visual step-by-step guides for each of the five core WP10 services. These tutorials are designed to help cities get started quickly and make the most of the tools available on the NetZeroCities Portal.

Annex 1.1.   How to browse the Knowledge Repository

The Knowledge Repository (KR) offers a structured and user-friendly way to explore technical solutions and practical resources that support cities in achieving climate neutrality. Below is a short walkthrough to help you navigate and use the KR efficiently.

Step-by-step: getting started with the Knowledge Repository

Step 1. Access the Knowledge Repository via the Portal

Visit: https://netzerocities.app/knowledge

No login or special access is required.

Figure 27: Landing page of the Repository landing page, with "Type" filter option displayed

Step 2. Start with a thematic area overview

Navigate to the **Quick reads** section (Figure 28) and select the page titled **Technical Innovation** (Figure 29). This age provides access to multiple thematic areas (such as *Energy generation* or *Mobility and transport*), which serve as gateways to grouped solution factsheets.

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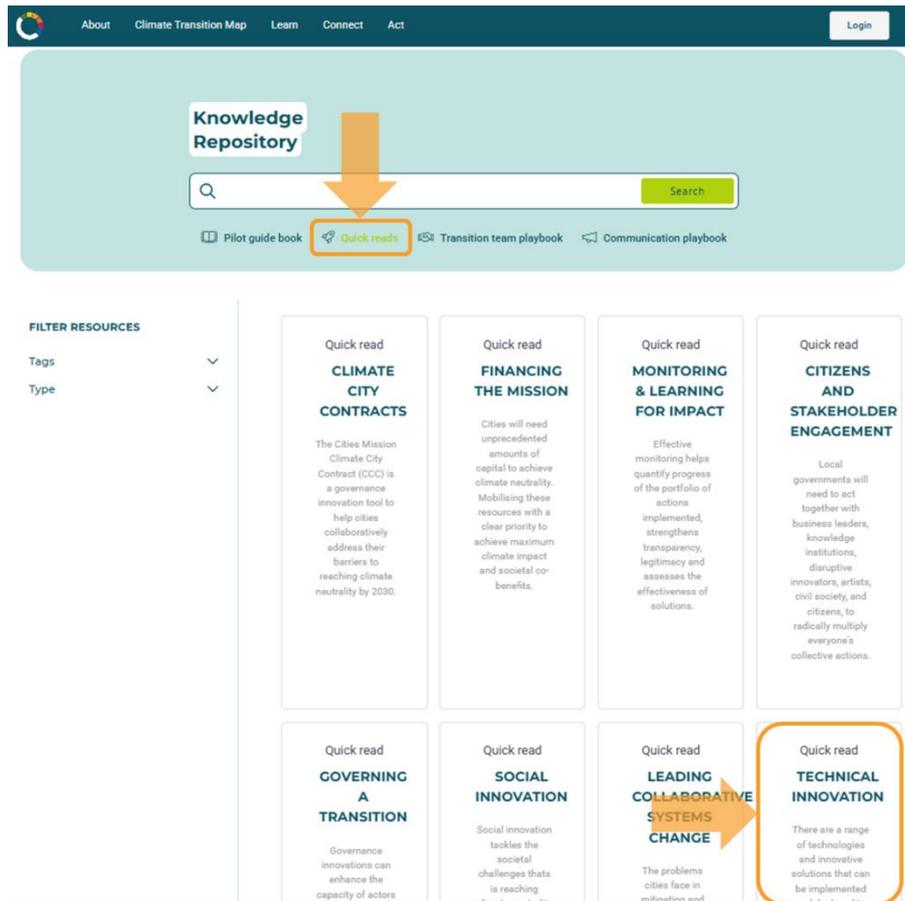
Figure 28: "Quick reads" access point within the Knowledge Repository
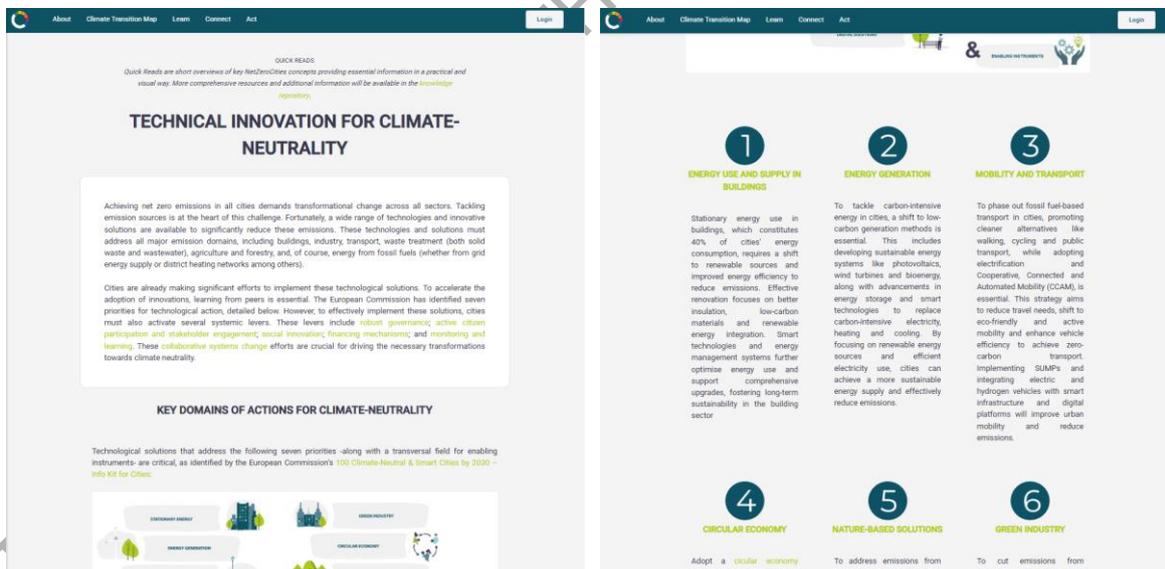
Figure 29: *Technical Innovation* quick read page, linking to thematic areas

Box 6. Extra tips to access thematic articles in the Knowledge Repository

You can also access thematic articles by:

- Using the keyword search on the main page and filtering by "Article" under "Type of resource", or
- Clicking the direct links provided in section 3.1 and Annex 2

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Step 3. Explore grouped solutions within each thematic article

Scroll to the bottom of a thematic article to find a list of related solution factsheets. These are grouped under the article's topic and link directly to detailed entries.
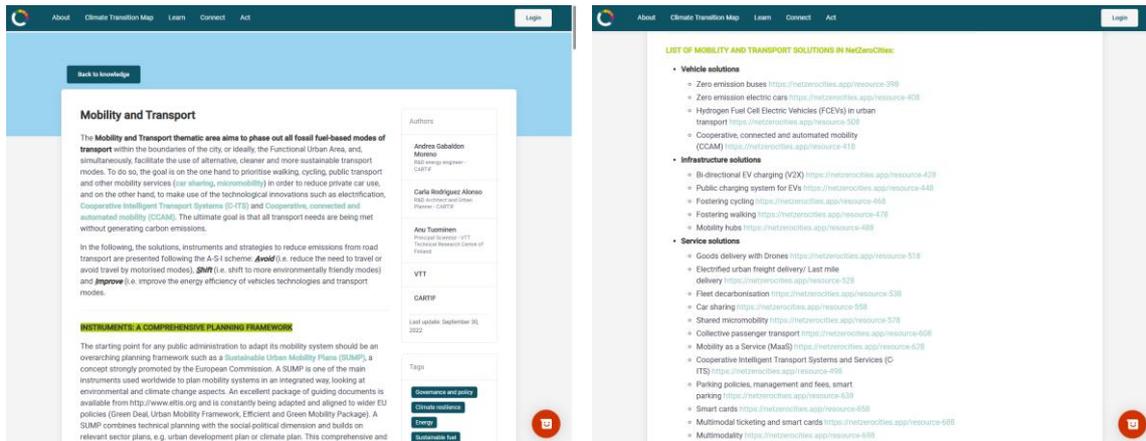
Figure 30: Thematic article on "*Mobility and Transport*", with grouped solutions displayed at the end of the page

Step 4. Browse solution factsheets

Each solution factsheet is structured to support quick navigation and decision-making. It includes:

- A summary of the solution with visuals.
- Associated **co-benefits** (e.g., resilience, health, equity).
- The list of keywords.
- Pre-conditions and **enabling conditions**.
- Constraints and **barriers** for implementation.
- Drawbacks and **adverse impacts** of the solution after implementation.
- External links to additional information and related resources.
- Indicators to explore impacts and DNSH alignment.
- **Instruments** and processes for **implementation.**
- Examples of real-world implementation and references.

Figure 31: Sample solution factsheet: *Municipal solid waste separation at source: pay as you throw*, **showing key information fields**

Step 5. Use filters and keyword search

To find specific content:

- Use the **search bar** at the top (Figure 32), or
- Apply **sidebar filters** to browse by type or resource or keyword (Figure 33).
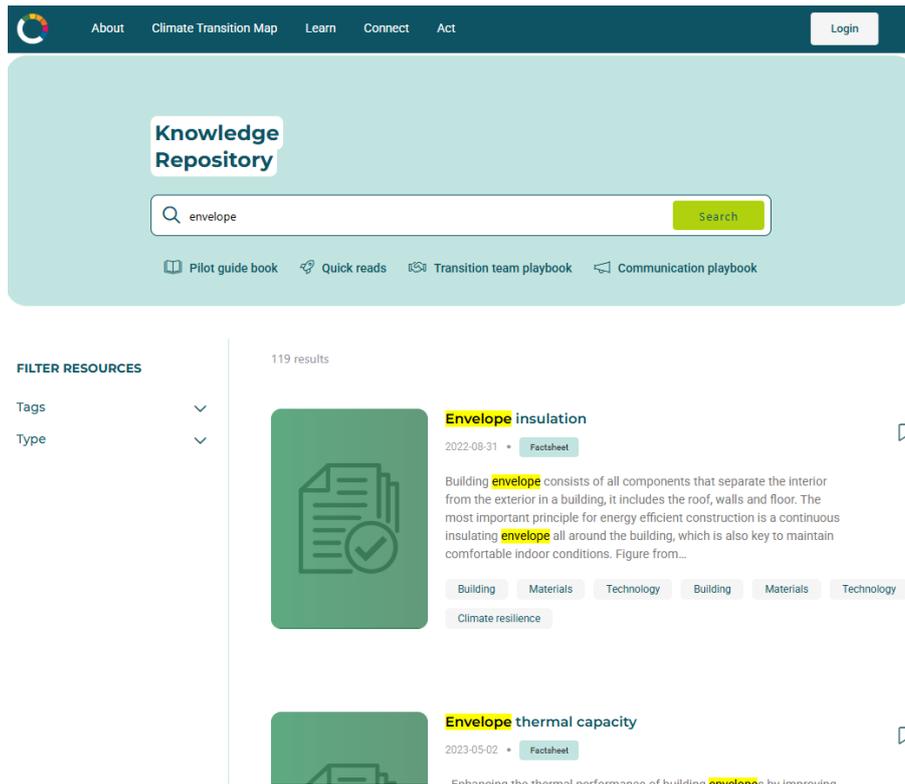
Figure 32: Using the keyword search function in the Knowledge Repository
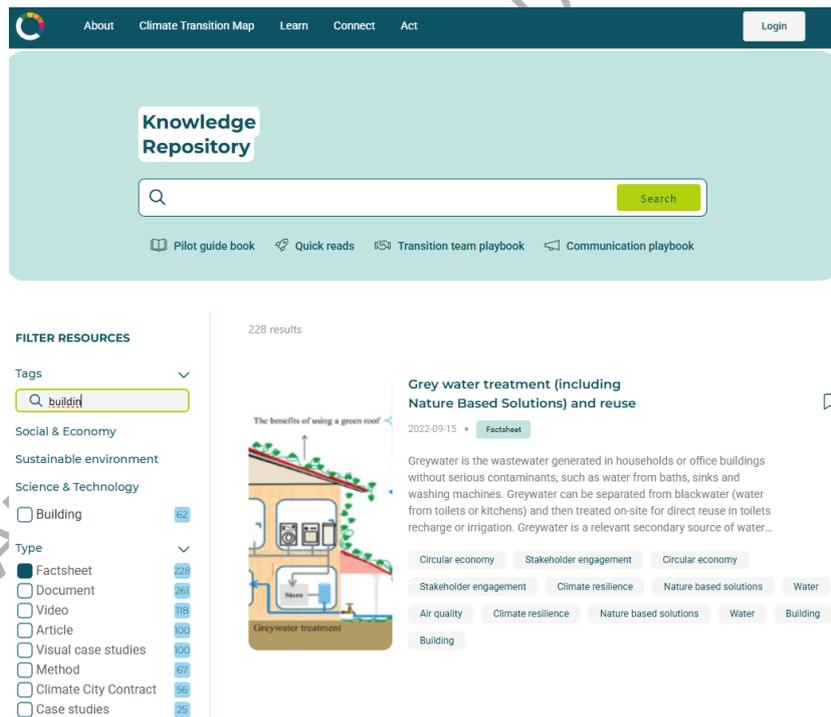
Figure 33: Applying sidebar filters to browse content by resource type or theme

Step 6. Rate, comment, save or share

Each factsheet includes options to:

- **Rate the resource** (e.g. for quality or relevance)
- **Comment** with feedback, deployment experience, or links to related content
- **Save or copy the link** to share with colleagues or stakeholders
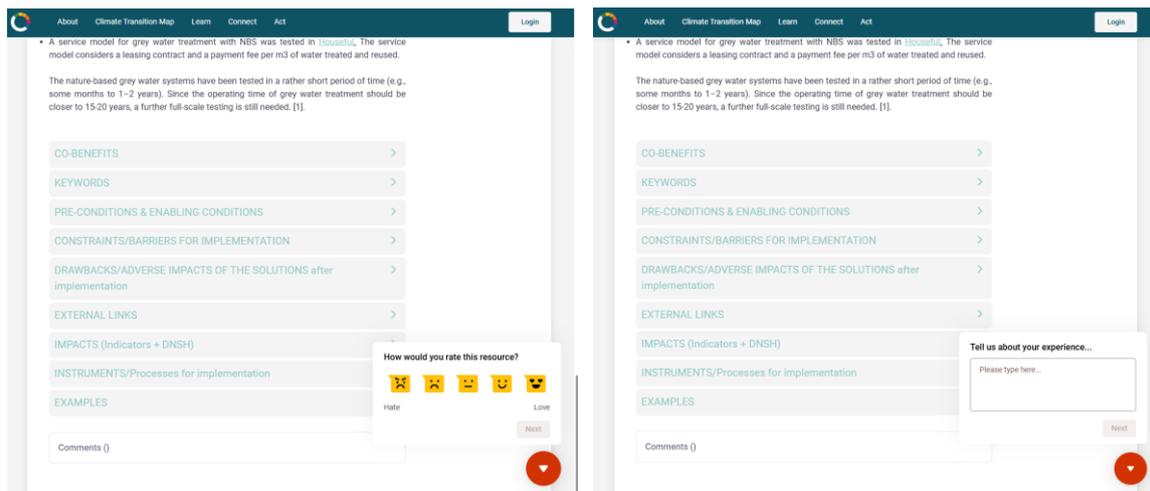
Figure 34: Engagement options at the bottom of a solution factsheet: rating and commenting

Did you know?

Box 7. Practical tips to get more out of the Knowledge Repository

- Combine the KR with the **Solution Outliner** to filter relevant options by barriers and city context.
- Use it in parallel with **Solution Bundles** to check how individual solutions connect within systemic actions.
- The KR supports both deep dives and rapid scans: use it early for exploration, and later to validate and detail selected solutions.

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Annex 1.2.   How to use the Solution Bundles tool

The Solution Bundles tool allows cities to explore climate actions as part of **integrated bundles** rather than isolated measures. Through an interactive 3D interface, users can see how solutions interconnect, where they could be implemented across different urban areas, and how to link them to technical details in the Knowledge Repository.

Below is a step-by-step walkthrough to help you make the most of the tool.

Step-by-step: getting started with the Solution Bundles tool

Step 1. Access the tool and explore related guides and resources

Go to the ACT section of the NetZeroCities Portal and open the Solution Bundles service:

https://netzerocities.app/solution-bundles

Figure 35: Finding the Solution Bundles within the NZC Portal

Before exploring the bundles, you may want to review:

- The **user guide** available within the tool.
- The **Learning Programme resources** (Section 3.4), which provide additional context on systemic approaches and portfolio development.

Step 2. Select a strategic bundle

Choose one of the four bundles that best matches your city's goals. In this tutorial, we will focus on the Carbon Capture, Storage & Removal Bundle as an example.
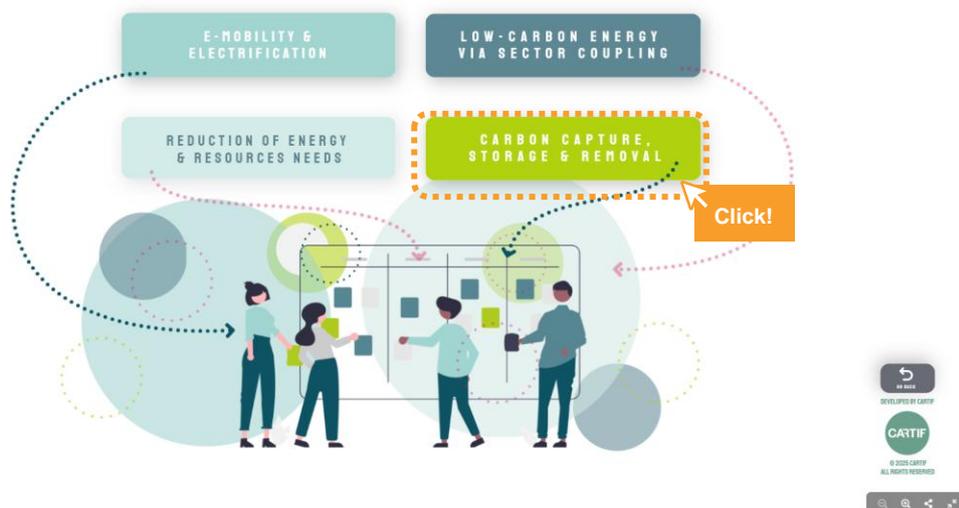
Figure 36: Homepage – Selecting a Bundle

Step 3. Read the introduction

Each bundle begins with a short **overview** structured in three parts: the core idea, why it matters, and what this bundle offers**.** This helps you quickly understand the systemic focus of the bundle.

In addition, a small **menu** on the right-hand side of the screen allows you to switch to another bundle**,** return to the home page, or access this mini-tutorial at any time.

Figure 37: Introduction of the Carbon Capture Storage & Removal Bundle

Step 4. Apply thematic filters

Use the **magnifying glass** filter to explore the bundle through WP10 thematic areas (e.g., stationary energy, mobility, circular economy, nature-based solutions).

In this mini-tutorial, we will choose the **Nature-Based Solutions** area. When you click on this section, the following **3D view** will appear (Figure 38).
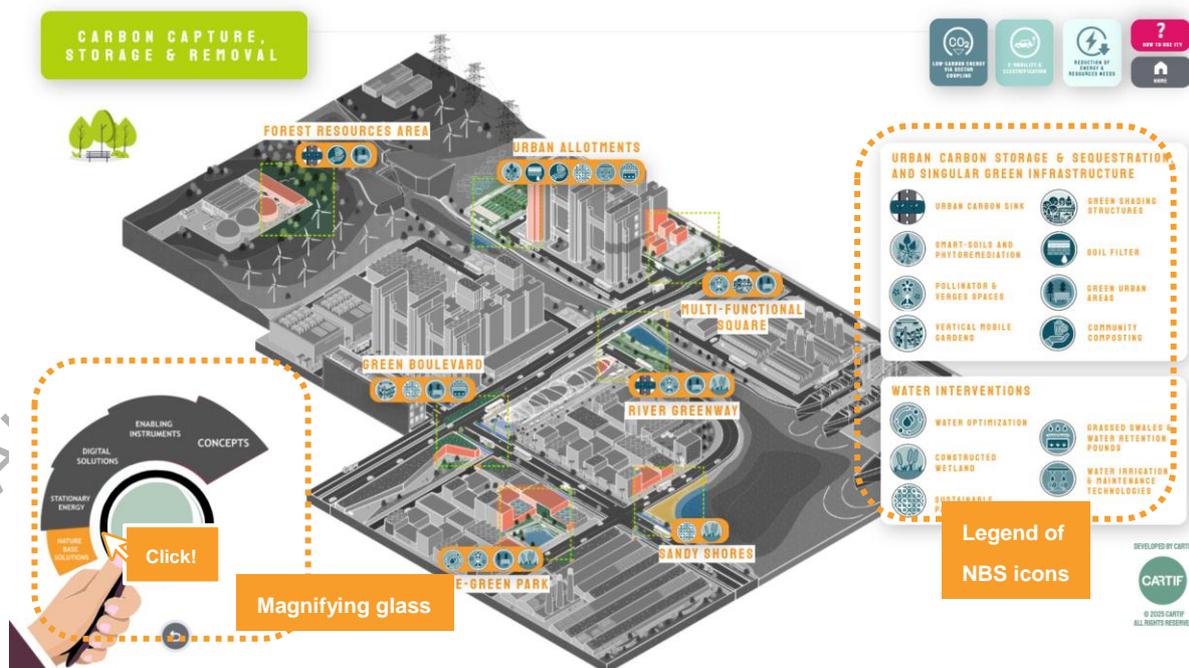
Figure 38: Nature Base Solutions Area in CCSR Bundle (1)

On the right-hand side of the screen, you will also find a legend of icons showing the technological solutions represented. Each icon is linked to specific zoom areas within the 3D environment.

Step 5. Navigate the 3D environment

Explore the city-like environment where solution icons are mapped to different urban areas such as Green Boulevard, Sandy Shores, Multi-Functional Square, and more.

This visualisation groups solutions by location, helping you identify where interventions could take place within the city and which areas may serve as strategic points of action.

In this example, we are interested in the **Vertical Mobile Gardens** solution, so we will go directly to the **Green Boulevard area**, where this solution is referenced.
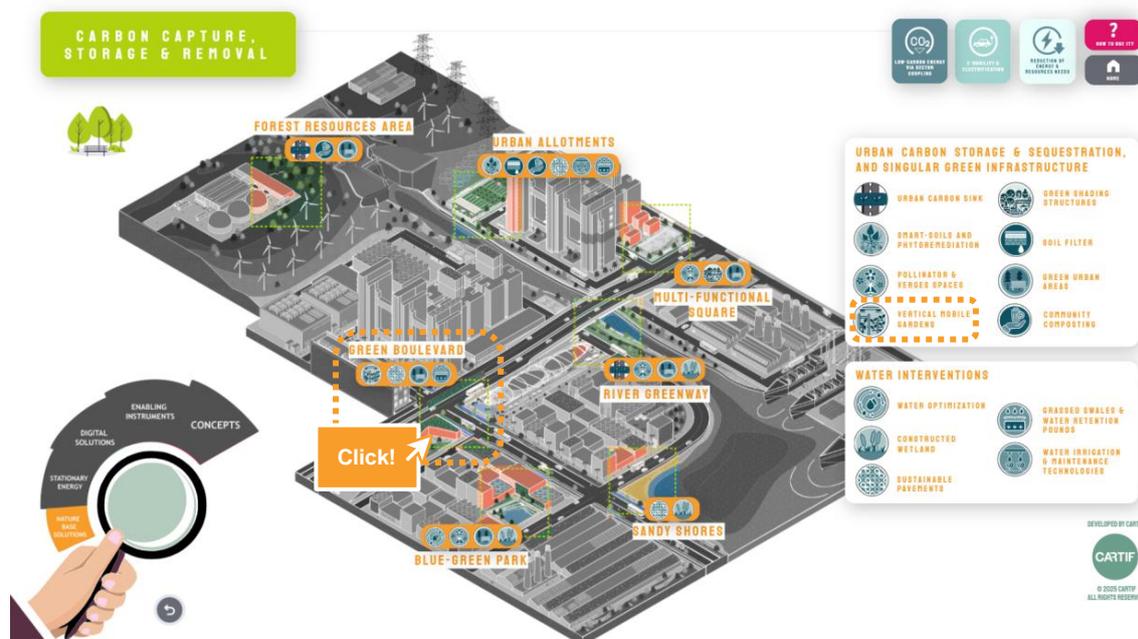
Figure 39: Nature Base Solutions Area in CCSR Bundle (2)

Note on thematic areas without zooms

Not all thematic areas are organised through zooms or intervention zones. Some sections, such as **Concepts, Enabling Instruments, Digital Solutions, and Circular Economy,** use a simpler interface, where solutions are directly linked to the **Knowledge Repository factsheets**.

In these cases, you can open the content either by clicking on the icons or directly on the solution titles

Mini example: The concept of the **Water-Energy-Food-Ecosystem (WEFE) Nexus approach** is presented in this format, giving direct access to its factsheet in the Knowledge Repository.

Figure 40: Clicking in WEFE Nexus Approach in Concepts Area

Step 6. Zoom in on priority areas

Look more closely at clusters of interventions to gain deeper insight into local implementation options. These zooms allow you to see how different measures can be combined within the same urban space to maximise climate, social and environmental benefits.

When you are already inside one of the information windows of a zoom area and hover over a case study, a **short description** will pop up. This gives you a quick insight into what the case study is about, helping you decide straight away whether it is of interest.

Figure 41: Green Boulevard Zoom in NBS Area

Step 7. Click on solution icons

Inside the window of a zoom area, click on the **icon next to the solution title** to open the linked **factsheet in the Knowledge Repository.** Each factsheet provides detailed information, including:

- A description of the solution and its applications.
- Co-benefits for climate, society and economy.
- Barriers and enablers to implementation.
- Examples and case studies from real-world projects.

This allows you to move from a visual exploration of bundles to in-depth technical knowledge that can support planning and decision-making in your city.

Figure 42: Clicking in the Factsheet of the Vertical Mobile Gardens

Step 8. Review case studies

Browse **the best practices and case studies** embedded in the tool to learn from other cities that have implemented similar measures. These real-world examples illustrate how solutions have been adapted to different urban contexts, helping you:

- Understand practical implementation steps.
- Anticipate challenges and enabling factors.
- Gain inspiration for replicating or scaling solutions in your own city.

In this example, **the Mobile Green Living Room (Germany)** shows how vertical mobile gardens can provide flexible greening options in dense urban areas.

If you click on the icon next to the case study title**,** you will be redirected to the original **reference, website or article** for that specific case study.
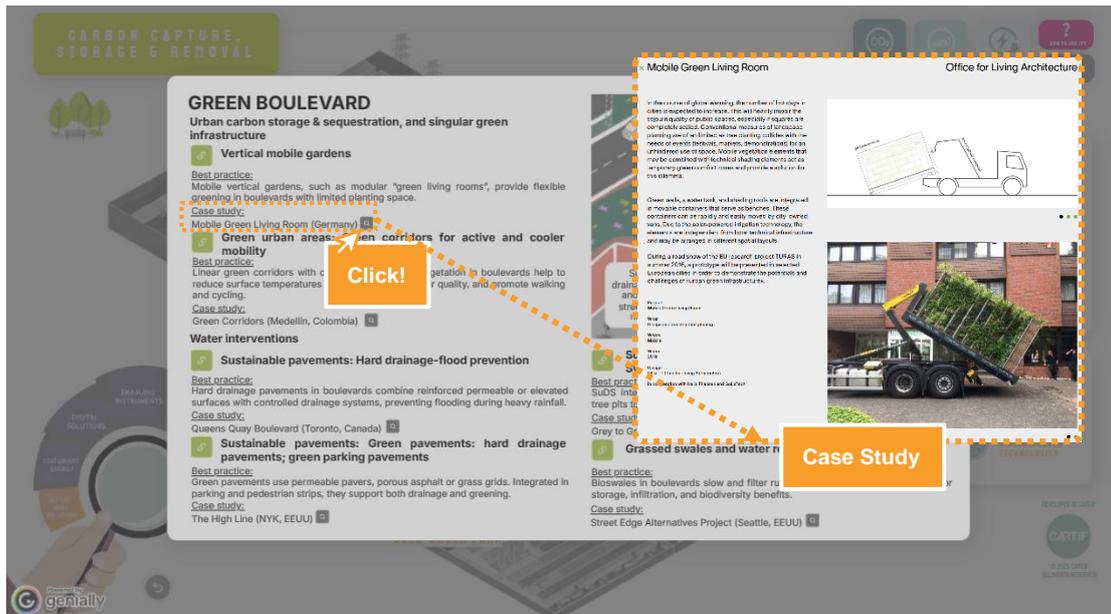
Figure 43: Clicking in the Case Study of the Vertical Mobile Gardens

Step 9. Use in workshops and planning

Bring the tool into stakeholder workshops or municipal meetings as a shared visual reference. It helps:

- Facilitate cross-department discussions.
- Co-design integrated portfolios of action.
- Refine and align Climate City Contract (CCC) actions with systemic and spatial insights.

By using the Solution Bundles tool in group settings, cities can create a common understanding and strengthen collaboration around climate-neutral strategies.

Box 8. Combining tools for actionable planning

Combine the Solution bundles tool with the **Knowledge Repository** for technical detail and with the **Solution Outliner** to prioritise solutions by your local context. Together, they provide a powerful pathway from exploration to actionable planning.

Annex 1.3.   How to use the Solution Outliner

The Solution Outliner helps cities **prioritise solutions** from the Knowledge Repository, based on their local context and ambitions. It allows Transition Teams to define key conditions (ambitions, barriers, enablers, co-benefits) and then generates a tailored list of solutions most relevant to their pathway towards climate neutrality.

Step-by-step: getting started with the Solution Outliner

Step 1. Review your city's context

Before starting, hold a Transition Team session to agree on your city's context conditions:

- **AMBITION Which sectors are included in the Action Plan, which is the city's climate ambition?** For each decarbonisation sector or domain, there will be some optimum or priority solutions over others. The tool will help the Transition Team select those ambitions that best fit their strategy.

- **CO-BENEFITS What co-benefits are you seeking to achieve with this ambition?** Envisage the outcomes or the co-benefits aimed at from your Action Plan. Each prioritised solution will impact differently on the city and the citizenship, and the Transition Team must have a systemic and collective vision to identify what co-benefits derive from the different impact pathways that the successive actions will allow to be achieved.

- **BARRIERS What can stop your ambition or make it fail?** To implement a successful Action Plan, the Transition Team must identify those obstacles or barriers that must be faced, both from a technical, social, or political point of view. Once again, the identification and mapping of these barriers must be defined collaboratively by the Transition Team.

- **ENABLERS What can serve as a lever or opportunity to promote the achievement of the ambitions proposed in the city's climate transition map?** In opposition to barriers, it is important to identify those elements of opportunity that make the Action Plan a more robust and viable instrument for the city's climate transition.

Figure 44: Transition Team co-creation before start using the tool
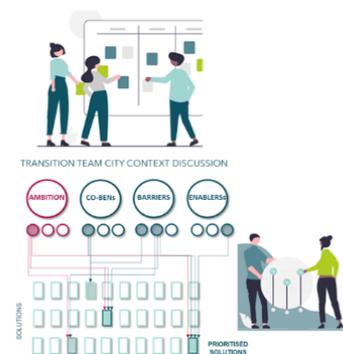
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Step 2. Access the tool and explore related guides and resources

Go to the ACT section of the NetZeroCities Portal and open the Solution Outliner service:

https://netzerocities.app/solution-outliner
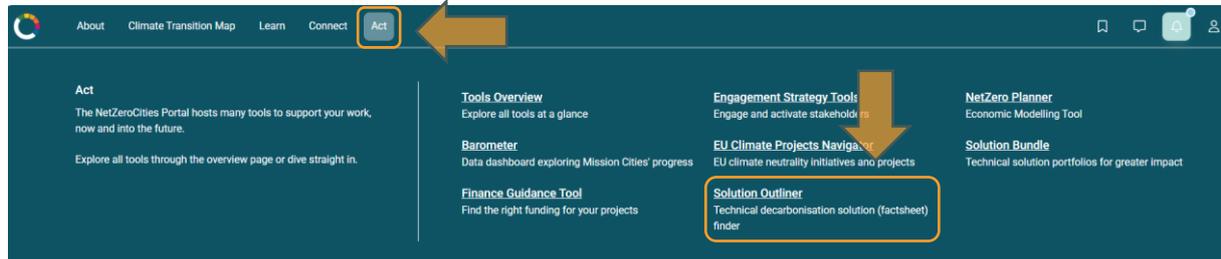
- NZC Solution Outliner user guidance
- NZC Solution Outliner tutorial video

SOLUTION OUTLINER

... ABOUT THE SOLUTION OUTLINER

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Why?

❖ To help cities confront the overwhelming amount of information to implement the most **appropriate actions** for their action plan
❖ To facilitate the work of municipal teams in defining the plan and thus focus only on those **measures and solutions that best adapt** to the needs of each city

How?

❖ Through a web tool that connects the **city's ambition with contextual information** (barriers, facilitators, co-benefits)
❖ Providing cities with a **preliminary and filtered list of solutions** with which to start working in a more manageable way.

What?

Levers for the tool:
❖ Search of practicality and simplicity
❖ Alignment with transition map process
Connectivity:
❖ With other tools developed within the mission platform

Added value of the solution outliner

❖ Gives cities the ingredients to define their portfolio of actions based on each context.
❖ And seek integration, synergy, and coordination between them.
❖ Simulate different scenarios and play with hypothetical situations, expanding the scope of the analysis

← BACK   CONTINUE →

Figure 45: A summarize User guide is also included as a functionality in the tool

SOLUTION OUTLINER

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... WHAT IF MY CONTEXT CHANGE?

The Solution Outliner allows the Transition Team to change the context conditions whenever necessary, not only if the context conditions change, but also when the Team wants to model a possible scenario different from the current one.

Is everything clear now?...

| No, I need more information | Yes! So let's start using the Solutions Outliner |

CHECK THE USER GUIDE

CHECK THE VIDEO

FIND SOLUTIONS FOR MY CITY

← BACK

Home

Figure 46: From this summarize guide you can explore both the complete guide and the video

Step 3. Select your ambition and context conditions

Select the GHG reduction ambition and relevant systems to act on (e.g., energy, mobility, buildings). This will help define the scope of your NZC pathway.

Instruments — Stationary Energy, Energy Generation, Green Industry, Mobility and Transport, Circular Economy, Nature-based Solutions — Digital Solutions

Figure 47: Ambition scope for the different thematic areas (related to GHG sectors)

Enter co-benefits, barriers, and enablers that reflect your local situation. These shape how the tool filters solutions.

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Figure 48: The selection screen in the tool where you can select the options for each parameter (Ambitions, Co-benefits, Enablers and Barriers)

Step 5. Check the filtered solutions

The tool provides a tailored list of solutions that best respond to the preselected ambition and context:

Figure 49: The selection screen in showing the filtered list that matches with the selection made

For each solution, there is a canvas sheet that summarises:

- Ambition/Context connection of each solution
- Factsheet link from the NZC Knowledge Repository
- Connection with the Solution Bundle tool
- Connection with other services (on development
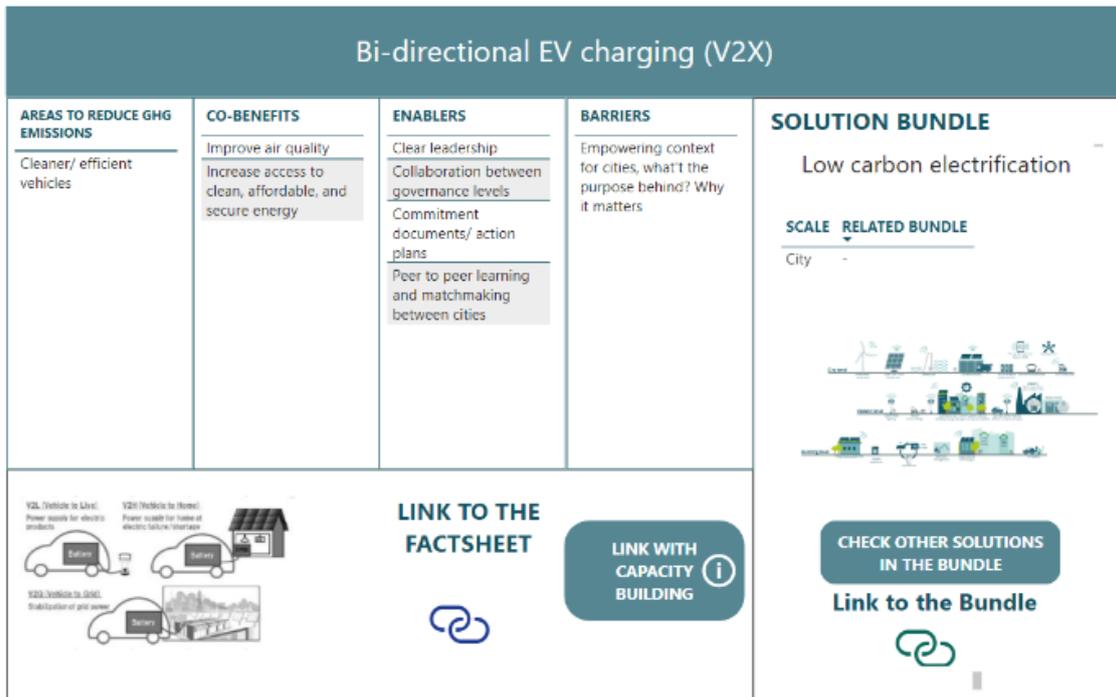
Figure 50: Solution canvas sheet summary

Step 5. Generate prioritised solutions

The tool offers the possibility to evaluate the most feasible solutions according to their priority, including a list of top 20 solutions.

These solutions can be reduced:

- Selecting other areas of action to identify possible synergies among solutions
- Selecting a bundle to identify the prioritized solutions included

Figure 51: Solution prioritisation screen

Step 6. Use results in planning process

Review the prioritised solutions as input to Climate City Contract updates, strategy workshops, or stakeholder discussions. You can re-run the tool with different ambitions or context conditions to test alternative scenarios.

Apply the prioritised solutions in:

- Climate City Contract updates.
- Strategy workshops and Transition Team sessions.
- Stakeholder engagement processes.

You can re-run the tool with different inputs to compare scenarios.

What cities can achieve with the Solution Outliner?

Box 9. From prioritisation to action planning

To maximize the benefits of the Solutions Outliner, cities are encouraged to:

- Use the tool in conjunction with other NetZeroCities resources, such as the **Knowledge Repository, NetZeroPlanner** and **Solution Bundles**.
- **Provide feedback and suggestions** for improving the tool and its integration with other NetZeroCities resources.
- **Engage with other cities and stakeholders** to share knowledge and best practices in climate neutrality planning and implementation.

Annex 2. List of all factsheets and resources developed under WP10

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

Table 1: Stationary Energy (Buildings) solutions

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

Energy Generation: https://netzerocities.app/resource-338

Table 2: Energy Generation solutions

Energy Generation	
RES electricity and thermal energy generation	Distributed wind
	Micro-hydropower generation in urban water networks
	Geothermal energy
	Co-generation systems
	Sustainable biomass and biogas power
	Fuel cells
Energy recovery	Waste heat recovery in district heating networks
Energy and E-fuel storage	Electricity storage: Chemical storage

Energy Generation	
	Thermal Energy Storage
	Seasonal storage (pits, dwells, etc.)
Infrastructure	From 3G to 5G District Heating and Cooling networks (generation to substations)
	Renovation of DH&CN (1G and 2G)
	Microgrids
Smart solutions	Energy management techniques

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

Table 3: Mobility and Transport solutions

Mobility and Transport	
Vehicle solutions	Zero emission buses
	Zero emission electric cars
	Hydrogen Fuel Cell Electric Vehicles (FCEVs) in urban transport
	Cooperative, connected and automated mobility (CCAM)
Infrastructure solutions	Bi-directional EV charging (V2X)
	Public charging system for EVs
	Fostering cycling
	Fostering walking
	Mobility hubs
Service solutions	Goods delivery with Drones
	Electrified urban freight delivery/ Last mile delivery
	Fleet decarbonisation
	Car sharing
	Shared micromobility
	Collective passenger transport
	Mobility as a Service (MaaS)
	Cooperative Intelligent Transport Systems and Services (C-ITS)
	Parking policies, management and fees, smart parking
	Smart cards
	Multimodal ticketing and smart cards
	Multimodality

Green Industry: https://netzerocities.app/resource-2643

Table 4: Green Industry solutions

Green Industry	
Energy Efficiency in Industrial Processes	Heat Recovery & Valorisation
	Energy Management Systems
	Monitoring Systems
	Replacement of equipment
Renewable Generation for Industrial Processes	Solar Thermal in industries
	High Temperature Heat Pumps
	Green Hydrogen Technologies in green industry

Circular Economy: https://netzerocities.app/resource-2615

Table 5: Circular Economy solutions

Circular Economy		
WASTE	**Municipal solid waste (MSW)**	Municipal Solid Waste separation at source: pay as you throw
		Municipal Solid Waste treatment: Anaerobic digestion for biogas production
		Urban biodegradable waste for compost
	Textiles	Circular textiles: Urban recovery and processing techniques, waste to feedstock optimization
	Electronics and ICT	Circular electronics and ICT: New processes & strategies for the recovery of Critical Raw Materials
	Batteries and vehicles	System level circular economy approaches in batteries
	Plastics	Plastic waste management
		Plastics: Expanding the use of bio-based and compostable materials
	Packaging	Circular packaging: Reducing demand for (over)packaging/ packaging waste, improved circular design and strategies that fully replace the need for packaging
	Construction and Buildings	Construction and Buildings: Optimal management of waste at the end of building life cycle
		Construction and Buildings: re-using local building waste
		Construction and Buildings: urban mining model to assess circular construction opportunities and optimize resource use and exchange
		Construction and Buildings: Residual Value Calculator
		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
	Other waste products	Reduction of raw materials, waste and integration of secondary materials
WATER	**Building level**	Greywater and rainwater reuse at building level

Circular Economy		
		Efficient treatment and reuse of un-segregated water at building level
ENERGY	**Energy Efficiency**	Industrial symbiosis assessment and solution pathways for facilitating cross-sectoral energy and material exchange
	Energy Generation – RES	Production of biofuel based on black liquor from the paper industry
		Waste to energy in buildings
		Guarantee the energy saving/production in buildings: "Contingen approach"
FOOD		Circular Food Systems
		Encompassing the full value chain of producing food for human consumption – valorisation of low value fish species

Nature-based Solutions and Carbon sinks: https://netzerocities.app/resource-2644

Table 6: Nature-based Solutions (NBS) solutions

Nature-based Solutions	
Urban carbon storage and sequestration, and singular green infrastructure	Urban carbon sink
	Smart-soils and phytoremediation
	Pollinator and verges spaces
	Vertical mobile gardens
	Green shading structures
	Floating gardens
	Green filter area
	Urban garden bio-filter
	Green resting areas, parks and urban forests, parklets
	Cooling trees
	Green corridors for active and cooler mobility
	Community composting
Water interventions	Hard drainage-flood prevention
	Grassed swales and water retention pounds
	Floodable park
	Green pavements: hard drainage pavements; green parking pavements
	Sustainable Urban Drainage Systems (SuDS)
	Water irrigation and maintenance technologies
	Constructed wetland
	Rain garden

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Digital Solutions: https://netzerocities.app/resource-2645

Table 7: Digital solutions

Digital Solutions	
Analytics modelling solutions	Predictive Modelling
	Digital Twin (Built environment)
	Local Digital Twin (Planning / Decision Making, cross-cutting)
	Scenario-based analysis (Mobility & Energy - One Model)
	Artificial Intelligence (AI) applications to climate neutrality
	GHG Monitoring from Space
	BIM and CIM (Building/City Information Model)
Urban Digital Platforms	Platform Architecture
	CO_2 Emission Trading Platforms
	City Dashboards
	Predictive Maintenance supporting tools
	Advanced Renovation Support
	Data and Solution Catalogues
Digital infrastructure	IoT Sensor & Edge Computing for Environmental Monitoring
Disaster and Resilience Management	Vulnerability and risk information systems
	Satellite and Geospatial Data
E-governance solutions	Citizen Participation Platforms
Digital Public Goods	Measuring & Monitoring (green & digital transition)
	Public Code Management
	Documentation of ownership of data
	Applying Open Standards
	Open Data Models & Ontologies
	Local Data Spaces Policy
	Living.in-EU / MIM Plus
	European Interoperability Framework for Smart Cities and Communities: EIF4SCC
	United for Smart Sustainable Cities (U4SSC) Publications
	Agile systems development (prototyping & sandboxes)

Enabling Instruments: https://netzerocities.app/resource-2646

Table 8: Enabling Instruments solutions

Enabling Instruments	
Educational, Capacity Building instruments	User Engagement for Energy Performance Improvement
	Local energy communities
	Cooperatives
	Educational activities on NBS

Enabling 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
	Capacity building and training
	Educational/ Capacity building barriers identification
Involving, Collaborating and Empowering instruments	Urban-scale environmental decision support system (DSS) based on EPC (Energy Performance Certificate) databases
	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
	Gender diversity considerations in urban mobility
Financial instruments	Loans for Energy Efficiency (EE)
	Blended finance for Energy Efficiency (EE)
	Road/ Congestion pricing in transport
Planning instruments	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)
	Sustainable Urban Mobility Plan (SUMP)
	Decarbonisation Plans for Industry
	City water resilience assessment
Policy instruments	Governance EU Climate Neutrality Framework
Regulatory instruments	Public procurement for innovative NBS and Green Infrastructure interventions
	Building Renovation Passport (BRP)
	Smart Readiness Indicator (SRI)
	Mobility Management
	Urban Vehicle Access Regulations (UVAR)
	Low-Emission Zones
	NBS and Green Infrastructure regulation and ordinances
	NBS and Green Infrastructure plans and strategy design and governance
	Building Material Passport (BIM-based)
Technical instruments	Turnkey Retrofit service
	Integrated Energy and GHGs scenario mapping tools
	NBS and Green Infrastructure Mapping

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Enabling Instruments	
	Analysis of City/ (Building) circularity
	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
	One-stop-shop for building renovation

Concepts that support climate neutrality city targets (combine several solutions together): https://netzerocities.app/resource-3228

Table 9: Concepts that support climate neutrality city targets

Concepts prioritised	Thematic Area
GHG emissions / Scope 1, 2 & 3	*ALL*
Carbon Dioxide Removal (CDR) / Negative emissions	Green Industry Nature-based Solutions
Urban heat island (UHI) effect mitigation - Nearly Zero Energy Buildings (NZEBs)	Stationary Energy Energy Generation
Near Zero/ Positive Energy Districts (PEDs)	Stationary Energy Energy Generation
Positive Energy Buildings (PEBs)	Stationary Energy Energy Generation
Eco-districts / Green neighbourhoods	Stationary Energy Energy Generation
Urban heat island effect mitigation – Evaporate Cooling	Energy Generation
Smart Grid	Digital Solutions
15-minute city	Mobility and Transport Enabling Instruments
Industrial symbiosis	Green Industry Circular Economy
Water-Energy-Food-Ecosystem (WEFE) Nexus approach	Circular Economy
Urban green space ecology	Nature-based Solutions
Carbon capture and storage (CCS) and utilisation (CCU)	Green Industry Circular Economy

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Annex 3.   Tag   recommendation   system   in NetZeroCities

Content governance issues were raised through the evolution of many tools conceived by the NetZeroCities consortium, such as the Solutions Outliner, the Solutions Bundles, or the progression in the tagging system of the Knowledge Repository. In all cases, the classification of information - conceived to help search, navigation, or operation (as in tools such as the Solution Outliner)- suffered from a risk of becoming difficult to govern in the long term, with the growth of information inputs and potential relations among them.

Conversations around this perceived risk led to the idea of **using AI capabilities to reduce noise and misunderstandings in classification of the information generated within NetZeroCities**, resulting in the development of two of models which interpret text in English and suggest two levels of consensual tags, one associated to general topics and emissions scopes, and a more detailed one, with specific topics of interest in the project.

This document describes the initial context and materials, process of development, and final form of the solution implemented.

Context and Development

In order to facilitate semantic search, recommendation systems, or other relational tasks in text corpuses (collections of text items), the most common strategy is to apply consistent -and ideally related or hierarchized- tags or labels to the different items. In the context of NetZeroCities, most information repositories have been already subject to tagging systems with different scopes and intentions, also evolving trough the journey of the project.

Table 10. Classifications in different parts of the project

Domain of Emissions
Stationary Energy (Buildings)
Mobility & Transport
Stationary Energy (Energy Systems)
Waste & Circularity
Other scope 3 emissions
AFOLU (Agriculture Forestry & Land Use)
IPPU
Cross-sectoral
Offsets (Green infrastructure & Nature-based solutions)
NZC Thematic Areas
Built environment
Mobility and transport
Energy systems
Circular economy
Nature (NBS, biodiversity, natural resources policies)
(Green) Industry
Adaptation
Learning and capabilities
MEL Topics
Built Environment & Housing

Energy Systems
Green Infrastructure & Nature-Based Solutions
Industry Trade & Commerce
Mobility & Transport
Waste & Circular Economy
Society & Governance

The use of AI -and, specifically, Machine Learning models- in this environment, is focused at seizing this tagging experience and content, in order to train a predictive model which can evolve with the project and ensure continuity and homogeneity in the archiving and internal relations of the information produced.

Model-wise, a tagging system is essentially a problem of text classification (predicting a tag or a set of tags to a text input). In this sense, using a well specified model for the task ensures a consistent application of tags, which is crucial for tasks like content filtering or document organization, where human subjectivity could lead to inconsistent future results. Broadly speaking, developing such a tool involves selecting the data input, as well as the architecture of the model, along with the implications of both.

Data

A first question in approaching this task is whether the information already tagged within NetZeroCities is consistent enough to be considered 'ground truth data' for modelling, thus the need for a thorough exploration of the initial content (data and tagging systems) and its behaviour when subject to modelling.

Two sources of data and a tagging system were initially identified as the human footprint of text classification efforts in NetZeroCities: the Actions-Database (a database populated by the consortium, which includes specific actions taken by cities in the context of the Mission, along with short text descriptions); and the portal's Knowledge Repository, which holds a diverse caseload of information inputs, such as meetings and training sessions results, factsheets, Climate City Contracts, among others, and holds larger and more elaborate texts, also including many cross-references and embedded material (such as videos or pdf documents).

Regarding the labelling sets, the system agreed upon by the consortium (MEL team) for this task. It is a two-tiered list that has enabled the standardisation of services and tools developed within the project. In the case of the Actions Database, the tagging system for level 2 (the most detailed) is already implemented and agreed upon, and the level 1 (the broader classification) is derived from level 2 (assigning one or more level 1 tags which match each level 2 tag). The Knowledge Repository, on the other hand, employs a different tagging system, out of which a large number of entries have been manually re-tagged by TECNALIA's team to match the Actions Database information, specifically for level 1.

Table 11. List of level 2 tags, along with their assigned level 1 tags.

Level 1	Level 2
Built Environment & Housing	Analytics modelling (Digital twin)
	Building Envelope Retrofits
	Land Use & Urban Planning (Business districts)
	MSW Collection
	Monitoring & data collection
	New Buildings (Urban Regeneration & Densification)
	Smart City & Digitalisation
	Urban Digital Platform (Open source platform)
Built Environment & Housing, Energy Systems	Combined Heat & Power (CHP)
	District Heating and Cooling

Level 1	Level 2
	Replacement of equipment (Energy Efficient Buildings and Equipment)
	Street Lighting & Traffic Lights
Built Environment & Housing, Energy Systems, Waste & Circular Economy	Energy & Heat Recovery
	Heat Recovery (Waste-to-Energy)
Built Environment & Housing, Green Infrastructure & Nature-Based Solutions	CCS / CCU (Emissions (also non-CO2) filtering & capture)
Built Environment & Housing, Industry Trade & Commerce, Waste & Circular Economy	Recycling & Waste Reduction
Built Environment & Housing, Mobility & Transport	Mobility Planning (15-Minute City)
Built Environment & Housing, Waste & Circular Economy	Building Reuse
	MSW Separation
Energy Systems	Bioenergy (biogas/biomass)
	Biofuels
	Biofuels (Compressed natural gas)
	Biofuels (Liquefied natural gas)
	Biofuels (Synthetic Fuels)
	Decarbonised power plants
	Distributed Energy Generation
	Energy Communities
	Energy Demand Management
	Energy Plan
	Energy Plan (Energy Sufficiency)
	Energy Storage
	Geothermal & Hydro Energy
	Green Procurement (Energy Procurement)
	Green Procurement (Renewable Energy Company)
	Hydroelectric power plant
	Hydrogen
	Local Energy Generation
	Natural Gas (Fossil)
	Photovoltaic (Solar PV)
	Renewable Energy Sources (RES)
	Solar Thermal
	Wind Power
Energy Systems, Built Environment & Housing	(Smart) Grids
	Building Heating and Cooling
	Heat pumps
	Lighting (LEDs in buildings)
Energy Systems, Mobility & Transport	Clean public transport
Green Infrastructure & Nature-Based Solutions	Soils
	Trees and Green Spaces (Biodiversity)
	Trees and Green Spaces (Blue-green infrastructure)

Level 1	Level 2
	Trees and Green Spaces (Carbon storage)
	Trees and Green Spaces (Nature-based solutions)
	Trees and Green Spaces (Re-)Forestation & Urban Greening)
Green Infrastructure & Nature-Based Solutions, Built Environment & Housing	Carbon Capture (CCS/CCU)
	Land Use & Urban Planning
	Land Use and Urban planning
Green Infrastructure & Nature-Based Solutions, Built Environment & Housing, Waste & Circular Economy	Streets infrastructure (Surface Albedo & White Concrete)
Green Infrastructure & Nature-Based Solutions, Energy Systems, Industry Trade & Commerce	Cattle & livestock
Green Infrastructure & Nature-Based Solutions, Industry Trade & Commerce	Soils (Fertiliser)
Green Infrastructure & Nature-Based Solutions, Industry Trade & Commerce, Society & Governance	Regulatory Tools (Climate Adaptation & Resilience)
Green Infrastructure & Nature-Based Solutions, Industry Trade & Commerce, Waste & Circular Economy	Soils (Food production & distribution)
	Soils (sustainable agricultural practices)
Green Infrastructure & Nature-Based Solutions, Mobility & Transport	Streets infrastructure (Cycling & Bike lanes)
Green Infrastructure & Nature-Based Solutions, Waste & Circular Economy	Water & Wastewater
Industry Trade & Commerce	New Work (Remote Co-Working Telecommuting)
	Ports & Fisheries / Harbour
Industry Trade & Commerce, Built Environment & Housing, Waste & Circular Economy	Green Procurement (Circular Construction)
Industry Trade & Commerce, Society & Governance	Business models & development
	Business models (Employment)
	Capability building (Education & Training)
Industry Trade & Commerce, Society & Governance, Waste & Circular Economy	Incentive schemes
Industry Trade & Commerce, Waste & Circular Economy	Biodegradable Waste & Food
	Packaging (Paperless)
	Repair & Reuse
	Repair & Reuse (Resource Hub/Warehouse)
Mobility & Transport	Airports
	E-Vehicles
	Fostering biking (bike sharing)
	Fostering multimodality
	Fostering public transportation (bus)
	Fostering rail (train)
	Fostering rail (tram)
	Fostering walking

Level 1	Level 2
	Fostering water Transport
	Mobility Planning (Bus Rapid Transit (BRT))
	Mobility Planning (Park-and-Ride)
	Mobility Planning (Suburban/Regional Mobility)
	Shared Mobility
	Shared mobility (cars)
Mobility & Transport, Energy Systems	E-Vehicles (chargers)
	EVs & chargers (Busses)
	EVs and chargers (Trucks)
Mobility & Transport, Industry Trade & Commerce	Last mile logistics (Heavy Vehicles)
	Mobility Planning (Corporate Mobility Management)
	Mobility Planning / Last mile logistics (Logistics & Freight)
Mobility & Transport, Society & Governance	Regulatory tools (Traffic & Parking Restrictions)
Society & Governance	Capability building (Cooperation & Networks)
	Capability building (Health & Nutrition)
	Capability building (Research & Analysis)
	Capacity and Capability Building (Administration)
	Citizen Engagement
	Citizen Engagement (Communication)
	Citizen Engagement (Inclusion & Accessibility)
	Incentive schemes (Subsidies mapping & sharing)
	Incentive schemes (Taxation system)
	Regulatory tools
Society & Governance, Energy Systems, Waste & Circular Economy	Green procurement (Certifications)
Society & Governance, Energy Systems, Waste & Circular Economy, Green Infrastructure & Nature-Based Solutions	Climate fund
Society & Governance, Green Infrastructure & Nature-Based Solutions	Climate budget
Society & Governance, Industry Trade & Commerce	Sustainable Tourism
Society & Governance, Mobility & Transport	Regulatory tools (Low/Zero Emission Zones & Congestion Charging)
Society & Governance, Waste & Circular Economy	Citizen Engagement (Behavioural Change)
	Citizen Engagement (Sustainable consumption)
Waste & Circular Economy	Circular economy
Waste & Circular Economy, Built Environment & Housing	Construction & Buildings (Raw material extraction)
Waste & Circular Economy, Built Environment & Housing, Industry Trade & Commerce	New Buildings (Construction & Materials)
Waste & Circular Economy, Society & Governance	Capability building (Awareness campaign)
	One-stop-shop (OSS)

Process of development

The second unavoidable question will then be how to specifically model this information to ensure robust results. Text classification is a task commonly framed within the realm of Natural Language Processing (NLP), a branch of artificial intelligence that enables computers to understand, interpret, and generate human language in a valuable and meaningful way.

When approaching problems through NLP, considerations include text transformation into machine-readable information (such as tokenization, stemming-lemmatization, or stop-word removal), text numerical representation (such as word frequency, counts, or more advanced techniques such as vectorization and embeddings) and, finally, the modelling step itself which can use traditional learning models (less accurate but faster and more transparent) for simpler tasks, or leverage contemporary and way more complex approaches (which in turn offer less explainability, and have larger computational needs).

A first exploration of the information contained in the sources selected targeted the recognition of relevant terms and combinations thereof, with a model light enough to allow reasonably fast iteration, and explainable enough to allow for inspection of the results in the tuning and development process.

The text transformation performed consisted in the elimination of links, the simplification of texts removing special and html characters and capital letters, the elimination of words except noun, verbs, and adjectives.

The numerical representation, in order to be able to visualize the impact of different terms in the predictions, was the TD-IDF frequency approach, which stands for Term Frequency (the quotient between the number of times a term appears in a document and the total number of terms in the document); and Inverse Document Frequency (which measures how unique or rare a term is across all documents in a corpus, using the logarithm of the fraction between the number of documents containing the term, and the number of documents); and it is calculated as a product of both. This approach is applied to both the title and body of each item (as it is the case of Knowledge Repository data), and it considers both single words and pairs of words (technically named n-grams of order 2).

After an initial benchmarking, the model selected for exploration was a Random Forest, a model which fairly balances performance and explainability, for allowing iterations over the assessment of the data. A Random Forest is a machine learning algorithm that combines multiple decision trees to make predictions. A decision tree is a type of machine learning model that mimics a flowchart. It uses a series of simple, yes/no questions to split data into smaller and smaller groups until a final conclusion or prediction can be made.

In this exploration, one model was performed for each tag and for the initial fitting of the model, two actions were crucial: first, balancing the sample (the input of texts) using an automated method called SMOTE (Synthetic Minority Oversampling Technique; a method used to address imbalanced datasets by creating new, synthetic examples of the minority class) and using a grid-search in the hyperparameters -the inner parameters for any machine learning model, such as *n_estimators* (the number of decision trees in the forest) and *max_depth* (the maximum depth of each tree) in a Random Forest model. Grid Search is a hyperparameter tuning technique that systematically works through multiple combinations of specified model parameters, exhaustively evaluating each combination to determine the best-performing set.

Model selection (the process of choosing the best-performing machine learning model from a set of candidates for a given task) was approached by iterative removal of unimportant terms which, in this case, are a product of inspecting term importance in the model. Three approaches to importance (called Feature Importance in Machine Learning, and roughly similar to variable impact in traditional statistics) were performed: node impurity (measures how mixed the classes are in a decision tree node); permutation feature importance (measures a feature's importance by seeing how much the model's performance drops when that feature's values are randomly shuffled) and; SHAP (uses game theory to explain a model's prediction by assigning a value to each feature that shows its contribution). Each iteration kept the 50% top features per method that appears in at least 2 of the three methods.

Several metrics and visualizations were leveraged to understand the robustness of an AI approach with the available data, through the exploration proposed, on the models obtained after preparation and selection. First, the accuracy of a classification model, which is expressed as a measure of the proportion of all correct predictions—including both true positives and true negatives—out of the total number of cases examined by a classification model. Second, the importance of terms that was used for selection

is visualized. Also, the confusion matrix is shown to understand proportions of true positives and negatives obtained, as a table that visualizes a classification model's performance by summarizing the number of correct and incorrect predictions for each class. Third the Receiver Operating Characteristic (ROC) curve is plot. ROC is a graph that illustrates the performance of a classification model using the True Positive Rate on the y-axis and the False Positive Rate on the x-axis.

Finally, some tests of overfitting are run. Overfitting is the situation in which a model learns the training data so well, including its noise, that it fails to generalize to new data. A series of iterations on splitting train and test data are run to ensure results are similar. To do so, the Area Under Curve of the ROC curve is calculated, as well as the standard deviation of the predicted results. If these become very different when the original data is split in many ways, then overfitting is most probably present.
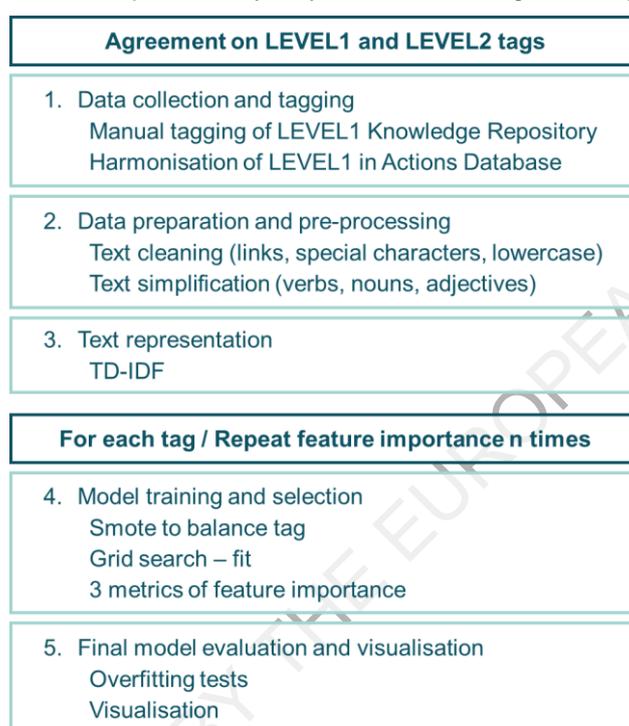
Agreement on LEVEL1 and LEVEL2 tags

1. Data collection and tagging
   Manual tagging of LEVEL1 Knowledge Repository
   Harmonisation of LEVEL1 in Actions Database

2. Data preparation and pre-processing
   Text cleaning (links, special characters, lowercase)
   Text simplification (verbs, nouns, adjectives)

3. Text representation
   TD-IDF

For each tag / Repeat feature importance n times

4. Model training and selection
   Smote to balance tag
   Grid search – fit
   3 metrics of feature importance

5. Final model evaluation and visualisation
   Overfitting tests
   Visualisation

Figure 52. Diagram of steps of the initial preparation and exploration

Conclusions

Based on our exploration, the quality of our training data's tagging system is paramount for successful text classification. Our findings revealed a critical trade-off: overly generalized tags, such as "Society & Governance," led to models that struggled to generalize and often relied on trivial or non-discriminatory terms for classification. This suggests that the information within these broad categories was too diverse and lacked the distinct patterns a model needs to learn effectively. Our conclusion that more specific and well-defined tags led to better performance is a key insight, as it confirms that a model's ability to learn is directly tied to the clarity and consistency of the "ground truth" labels we provided.

Given these conclusions, we need a two-pronged approach. First, we must critically re-evaluate and refine our broad, struggling tags. For categories like "Society & Governance," we should consider whether they can be broken down into more specific sub-categories that represent distinct topics or themes. This will provide the model with a clearer signal and a more manageable learning task. Second, for cases where our tagged content is scarce, we can use data augmentation techniques, such as SMOTE, to synthetically generate new examples for the underrepresented classes. By creating more relevant and diverse training data, we can help mitigate overfitting and ensure our models have enough content to learn the underlying patterns, even when a specific tag has limited real-world examples.

Finally, although our initial models are light and reasonable, many trivial words seem to make it into top positions of feature importance, leading us to think that a larger and more complex model would be of better use. Also, considering the evolution and growth of the information, a pre-trained model is also an advantage so as to avoid much manual inspection every time models are reviewed.

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mobility_&_transport: 23.4% of original rows tagged
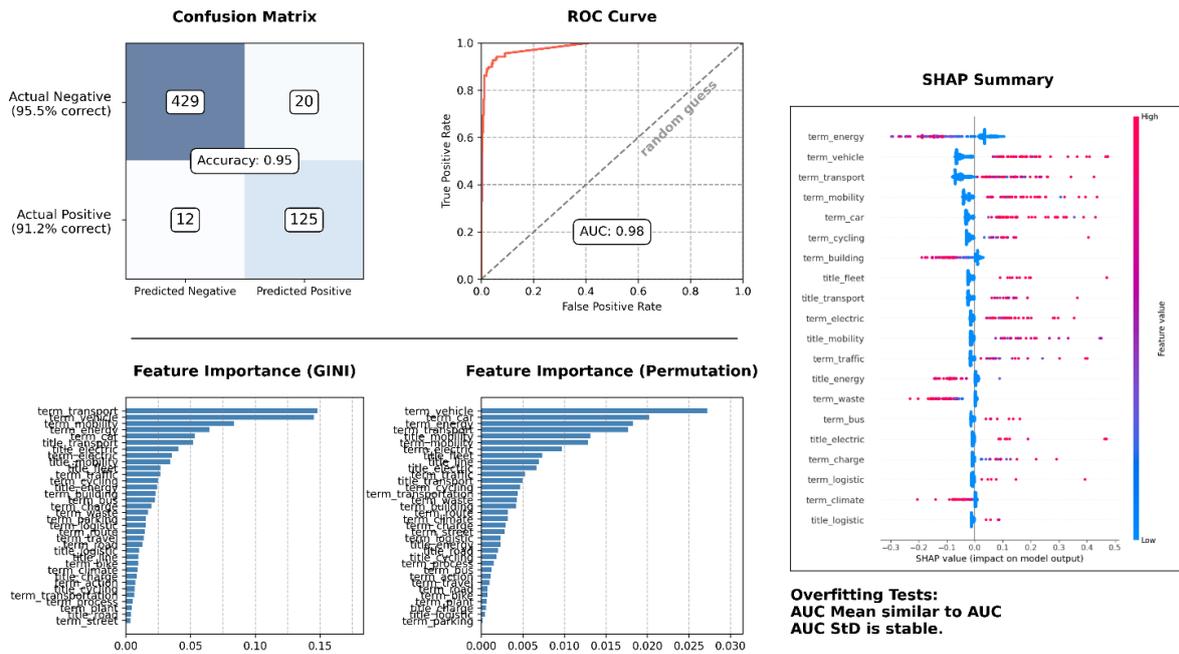
Figure 53. A well specified model (Mobility and Transport). A large number of the original inputs was tagged, hitting a high percentage of true positives and negatives, and relevant terms in all Feature importance approaches

society_&_governance: 29.3% of original rows tagged

Figure 54. A poor model caused by generalistic tagging (Society and Governance). Actual positives are just as good as a random guess, and relevant terms are illegible and different in all three approaches

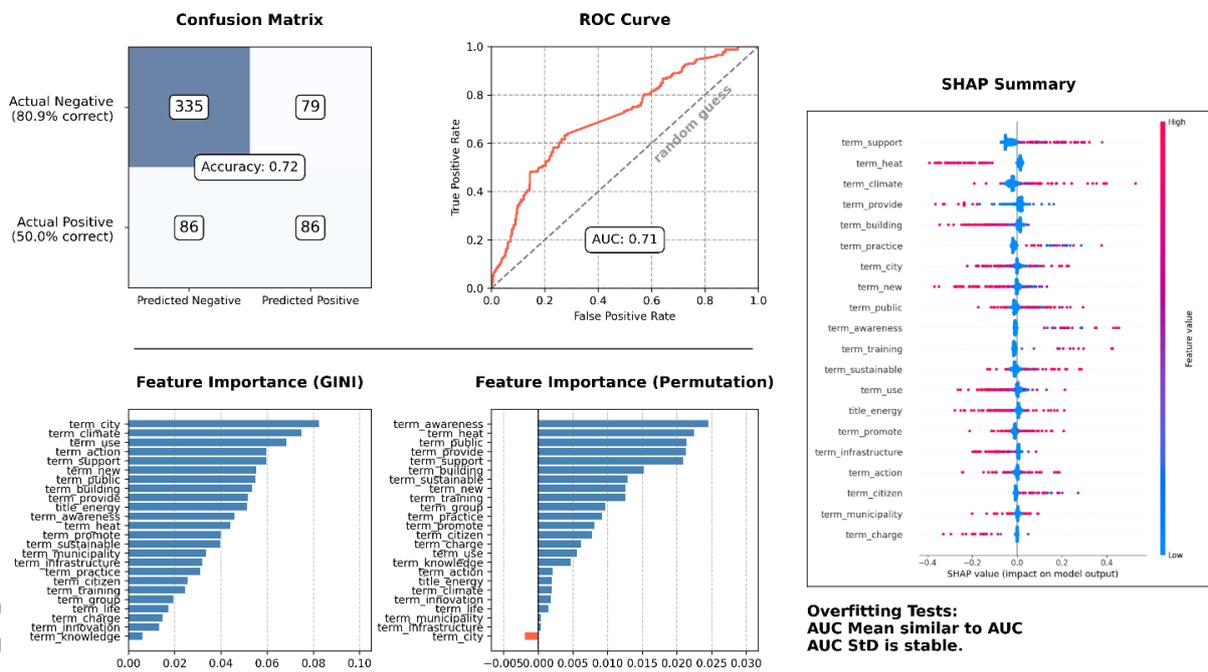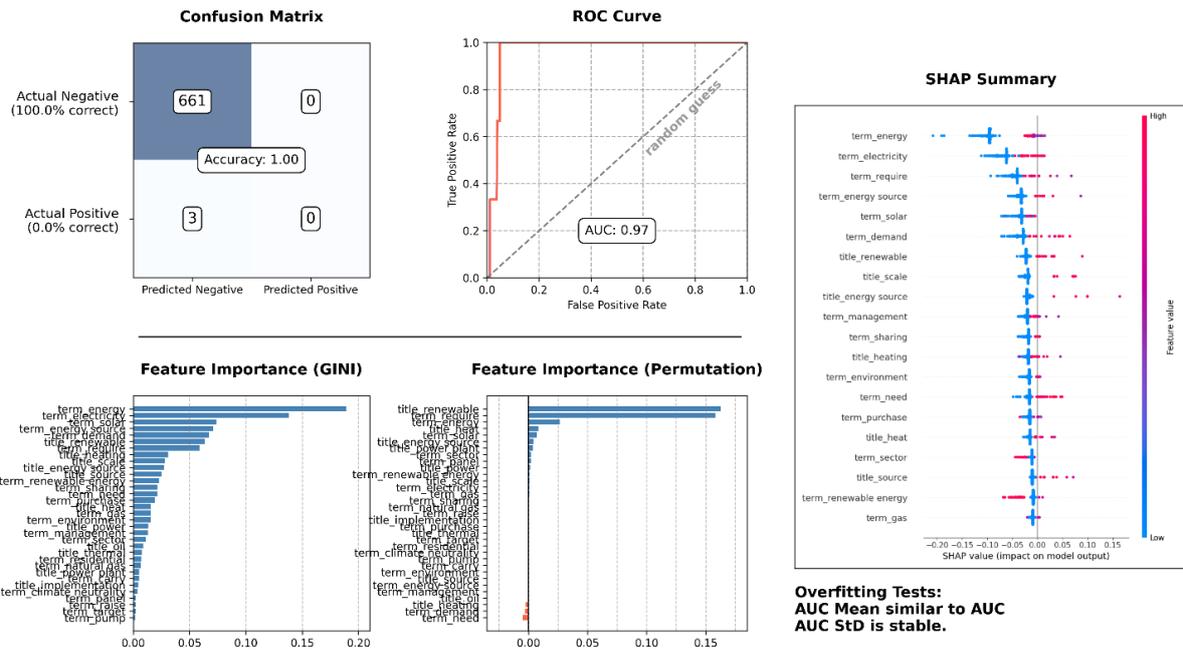Figure 55. A very poor model caused by scarcity of input data (Distributed Energy Generation). Although accuracy is 1, we can see how no true positives were obtained. Terms in Feature Importance are relevant, but this might be due to the small sample (3 entries)

Final Model

Two models have been developed using a pre-trained text model, namely DISTILBERT model, which is a lighter version of BERT, a deep learning natural language processing model developed by Google in 2018, available in huggingface.co for free use up to certain volume. This model has the ability to understand the context of words in a sentence bidirectionally, analysing both preceding and succeeding text. The final models are light, and able to predict probabilities of a tag being applicable to any input text. Also, the models allow for a multi-tag training that is stored in a single model and make it easier to implement elsewhere.

De main advantage of using DISTILBERT is that, instead of training a model from scratch, we leverage a pre-trained understanding of language (its knowledge of grammar and word meanings). The process involves **fine-tuning** the pre-trained model with our own labelled data. During fine-tuning, the model learns to associate text features with the specific labels you've provided. Once fine-tuned, the model can accurately predict the correct label for new, unlabelled texts.

In action, the models leverage mainly Transformers and PyTorch for implementations in Python. This has the advantage of being open-source and self-contained for implementation within the NZC infrastructure, without further ownership issues.

Also, it is trained using raw text, without needing previous transformations of the input text, making it very suitable for our goal. Furthermore, the fact that it is a multi-label model, implies that many labels can be suggested in each prediction, without each tag not being exclusionary of other tags.

A consideration learned from the previous exploration, however, is that the final process has involved oversampling of text inputs, in order to obtain better generalizations, as the impact of very sparsely tagged entries is strong. We have used a workflow of Random Word Augmentation. Essentially, it takes the entries of minoritarian classes and performs a random process of synonym replacement, insertion of synonyms of random noun, verbs or adjectives already present in the original inputs, swapping of sentences and words, and deletion of words. This way, it generates 'synthetic' text entries based on the minority classes, and significantly helps DISTILBERT generalizing the output.

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Implementation

In practice, each model consists of several files which give different input configurations to run, all of them expected by the main libraries needed to load the model: datasets and transformers. TECNALIA provides a requirements.txt so as to describe the necessary Python environment needed.

config.json
model.safetensors
special_tokens_map.json
tokenizer.json
tokenizer_config.json
training_args.bin
vocab.txt

Two models have been trained for each of the tag groups, which are named level1 and level2, each of them stored in a dedicated folder, and provided by TECNALIA.

The models are best loaded using Python's HuggingFace related libraries, needing three steps, **which will be provided as a simple Python (.py) module by TECNALIA** with all necessary imports and a single function which orchestrates:

- Tokenization (transformations to the input text needed by the models)
- Prediction (actually passing a text into the model)
- Prediction Probability and filtering (yields probabilities of prediction)

The model predictions have the shape of Python dictionaries with labels as keys and a number between 0 and 1 as values, and can be filtered to a minimum expected prediction **agreed by the consortium. TECNALIA will also provide a JSON file with necessary mappings between the format used in the models (lowercase underscore-separated) and the text that should be displayed in the website (normal writing)**

These dictionaries, easily converted to JSON format, should be stored in the Knowledge Repository DB (or any other means in which the information is stored by the owner) as JSONS associated to each resource, in two columns (level1 and level2 tags).

The general idea of these JSONs is that, when they have the value 1, it means that the specific tag has been validated (accepted) by a human and, when the value is a float number (different from zero and higher than the aforementioned threshold), it means that it is still a suggestion from the model.

We believe that an interesting way of displaying this in the website is by controlling the opacity of the tag in the front end, yet this is out of our scope and should be agreed by the consortium.

Regarding the implementation of the model, the general idea is that it should be loaded only when a user is editing or adding new information. The model should receive only a string (a text input), and it will yield predictions when run.

Additionally, this step should have minimum requirements for being able to receive an automated tagging. A minimum text size with a description of the content should be provided if the entry is not particularly textual (say, a video, or an embedded document), in which the topics treated should be made clear. The minimum text size for the description should be agreed by the consortium.

This could be achieved in many ways and should be agreed by the consortium: It could be called upon clicking a 'suggest tags' button, it could be smoother and run whenever a user changes the string in a particular place, etc. In any case, the models run very fast if fed with a single text input.

Another issue to be agreed on is the ability (or not) to re-tag or modify the existing entries in the Knowledge repository. After the validation, all entries will have a robust tag set, but we could let the model suggest new tags or validate the existing ones. This point also should be agreed on.

Finally, a list of both tag levels should be displayed when editing/uploading content. This list should be in normal text format and provided by the aforementioned mapping JSON. If agreed by the consortium, a thematic colour palette could be useful for users to navigate the extensive list of tags.

Validation

The first version of the automatically tagged resources can have misclassifications derived from noisy inputs, sparsely tagged training data (tags which seldom appear in the actions database), among others.

The first version of the tagging should not be published in a production version, but rather in a test / develop one, in order to make it visible for consortium members only (or have user / specific credentials).

After the first iteration, content owners will curate and validate the tagged Knowledge Repository so as to ensure the final tagging is perfect.

After validation, **TECNALIA will run a new version of both models, now having the tagged Knowledge Repository also as input training data and provide the new version which will simply substitute the first version.**