NET ZERO CITIES
SGA-NZC

Learning Resources and User Guidance for NetZeroPlanner

Deliverable D1.7

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Abbreviations and acronyms

Acronym	Description
NZP	NetZeroPlanner
FAQ	Frequently Asked Questions

Summary

This report presents the development and structure of user guidance for NetZeroPlanner (NZP), a modelling tool that supports cities in achieving climate neutrality through data-driven planning and investment strategies. The guidance is designed to accommodate a wide range of users—from beginners to experienced modellers—by offering tiered resources that facilitate progressive learning. These include a Quick Start Guide, introductory overviews, structured training modules, and advanced technical annexes detailing the model's structure, discount rate methodology, and frequently asked questions.

The guidance materials are organised into self-paced learning modules and accessible web-based resources, enabling users to navigate the tool, input city-specific data, assess decarbonisation pathways, and analyse economic outcomes. A significant milestone was the release of a NetZeroPlanner Learning Journey in November 2024, complemented by targeted resources addressing advanced user needs.

The report emphasises that user guidance is dynamic, evolving alongside model updates and user feedback. NetZeroPlanner is positioned not only as a technical tool but also as a capacity-building platform for climate action planning. Looking ahead, continued refinement of the model and its documentation will ensure its ongoing relevance and effectiveness for climate transitions in European cities.

Keywords

Economic modelling, user guide, climate action, investment planning

Introduction

Achieving climate neutrality is a complex challenge that requires cities to make informed, data-driven decisions about emissions reduction strategies, investment planning, and policy implementation. NetZeroPlanner (NZP) is designed to support cities in this process by providing a structured modelling tool that helps assess decarbonisation pathways, allocate costs and benefits, and evaluate the economic case for climate action.

This report focuses on the development and structure of the user guidance for Net Zero Planner, ensuring that a wide range of users—ranging from beginners to experienced modellers—can effectively engage with the tool. The guidance materials include a variety of resources, from introductory documents that help new users navigate the tool, to advanced technical annexes that provide detailed explanations of the model's structure, assumptions, and calculations.

Given the evolving nature of both NetZeroPlanner and its user base, the guidance is designed as a dynamic resource, continuously updated based on user needs and model enhancements. The development process has been iterative, incorporating insights from diverse contributors, and was recently strengthened by a gap analysis conducted between December 2024 and February 2025. This analysis led to the creation of new targeted resources that address specific technical aspects of the model, particularly for advanced users.

The following sections outline the approach taken to develop user guidance, describe the available learning resources, and highlight how they are structured to facilitate progressive learning. This report serves as a reference point for understanding how NetZeroPlanner supports its users in effectively leveraging the tool for climate action planning.

Process for developing the user guidance

The user guidance has been continuously refined throughout the development, release, and post-release phases of the tool, incorporating insights from both users and the project team to address key needs effectively. A dynamic and ongoing dialogue with city users has played a crucial role in shaping the learning programme, ensuring that the guidance remains relevant and responsive to real-world challenges.

The first milestone in this process was the release of a Learning Journey for the NetZeroPlanner in November 2024 to accompany the release of the tool. A Learning Journey is a structured path that helps Portal users build and apply knowledge and skills through collaborative, context-specific learning while working toward climate neutrality (see NZC D3.2 for further detail).To further enhance user support, a comprehensive gap analysis of the available guidance was conducted within the consortium between December 2024 and February 2025. This analysis identified areas requiring additional clarity and depth, leading to the creation of four specialised documents tailored for advanced users. These supplementary resources provide detailed insights into the model structure, key assumptions, a technical FAQ, and the methodology for discounting future benefits and costs, ensuring that users have access to robust and well-rounded guidance.

Overview of Learning Resources

This section gives an overview of the available user guidance. It follows the flow that the user can access information on the NetZeroPlanner web pages, starting with the essentials of getting to know the tool, then stepwise proceeding towards more advanced information on how the model works, what key input is needed, and how output is generated.

Getting Started

On the NetZeroPlanner Landing Page, the user gets access to clickable information via four interactive tiles to get started with using the tool, as well as a direct link to launch the tool itself. The page contains a quick start guide, basic information about the tool, and links to additional resources for learning and support (Figure 1).

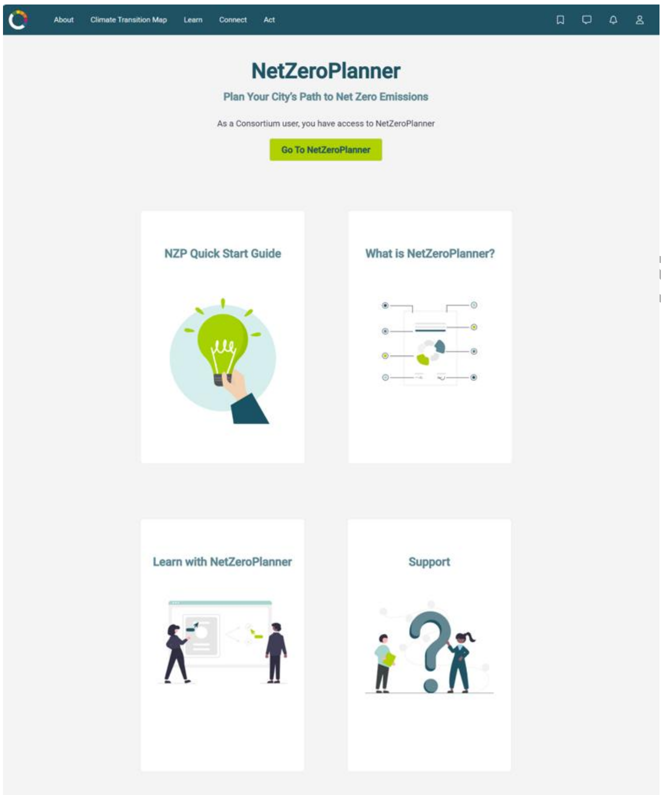

Figure 1. NetZeroPlanner landing page with basic learning resources

The **NetZeroPlanner Quick Start Guide** tile provides users with an initial overview of how to navigate and utilise the tool effectively. It offers step-by-step instructions on accessing NetZeroPlanner, creating a Climate Action Plan (CAP), inputting city-specific data, and analysing emissions forecasts. The guide also explains how to assess the economic case and co-benefits of decarbonisation strategies, run scenario comparisons, and track progress using the built-in monitoring tools. By structuring information in a clear and actionable format, the guide ensures that users can quickly understand and apply key functionalities to develop and refine their climate neutrality plans.

For users who prefer visual learning, a 50-minute webinar is also available under the Quick Start Guide. This recorded session provides a walk-through of NZP's features and demonstrates, step by step, how the tool can be used to support climate action and investment planning. It guides users through the process of entering key data and generating outputs that are relevant to their city's climate neutrality goals.

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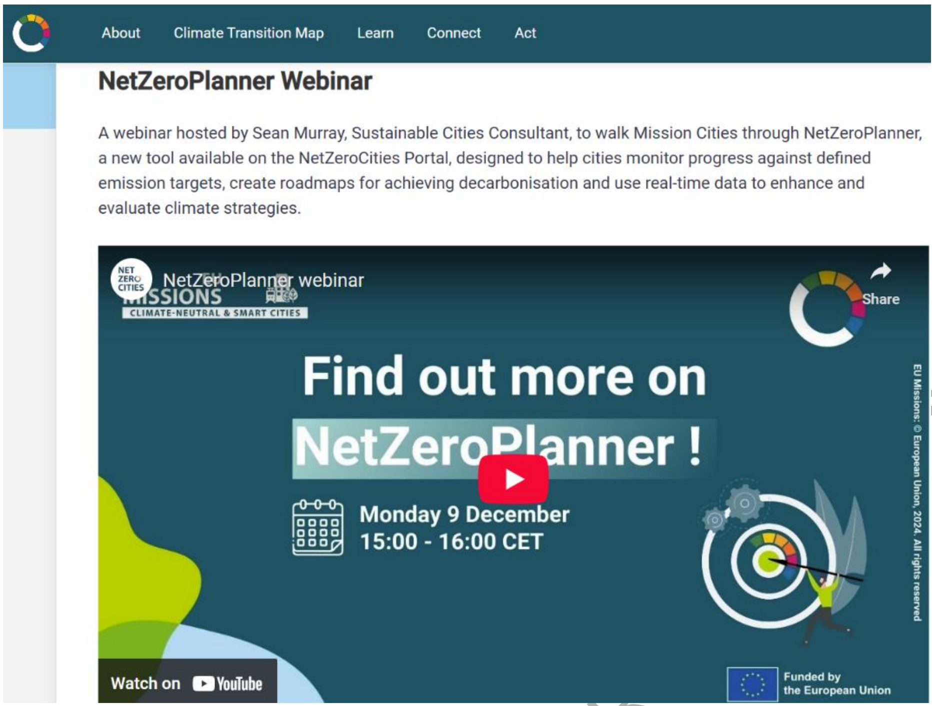

Figure 2. Walk-through webinar

The **"What is NetZeroPlanner?"** tile introduces users to the tool's core functionalities and purpose. It explains how NetZeroPlanner supports cities in developing, refining, and managing Climate Action Plans (CAPs) by providing data-driven emissions-reduction roadmaps. The guide highlights the tool's ability to allocate costs and benefits across carbon sub-sectors and stakeholders, ensuring optimised investments. It also outlines who can use NetZeroPlanner, from cities starting their climate planning to those refining existing CAPs. Additionally, it emphasises the tool's reporting features for tracking progress and invites users to join the NZC portal for further learning and support.

The **"Learn with NetZeroPlanner"** tile introduces a structured learning programme designed to help city climate teams effectively use NetZeroPlanner for decarbonisation planning. It outlines five training modules, combining self-study and group sessions, to enhance understanding of Climate Action Plan assessment, investment planning, and funding strategies. The programme is flexible, allowing users to engage with specific modules based on their expertise and needs. Additionally, the guide encourages participation in the **NetZeroPlanner: Building a Strong Economic Case** portal group, where users can access learning materials, collaborate, and exchange insights with peers. Module topics range from tool navigation to economic case development.

The "Support" tile provides users with access to additional help related to NetZeroPlanner. This includes a clear and user-friendly FAQ section, which addresses common questions about using the tool – such as how to access it, input data, or understand results. If users experience any technical issues while working with the tool, the Support section also provides a direct contact link to the technical support team, ensuring that assistance is available when needed. These resources help users troubleshoot independently or reach out for help, supporting a smoother experience with the tool.

NetZeroPlanner Learning Resources

When clicking on the *Learn with NetZeroPlanner* tile from the landing page, users are direct3d to the **Learning Programme**, which is hosted in the portal group *NetZeroPlanner: Building a Strong Economic Case.* This group acts as the central hub for training, peer exchange, and capacity building around the use of the NetZeroPlanner tool.

The Learning Programme supports cities through the NZP Learning Journey, guiding them in using the tool to advance their Climate Action Plans.

Structured around five modules – KickOff, Model Overview, Using NetZeroPlanner, Economic Case and Plan Iteration, and Reflections – the Learning Programme enables self-paced or group-based learning tailored to cities' context and needs. These modules reflect key stages in the Learning Journey approach outlined in NZC's Capacity Building Framework. These modules follow a logical flow from basic information towards more advanced information about the model design. The user can follow this sequence in this specific order to follow a self-organised or group-organised training programme or access the user guidance documents individually (see Figure 3 below).

To access the materials, users can take the following steps:

1. Click on the Learn with NetZeroPlanner tile on the NZP landing page.
2. Join the group NetZeroPlanner: Building a Strong Economic Case (if not already a member).
3. Navigate to the "Learning Materials" tab in the group menu.
4. Select a module heading to open its resources.
5. Optionally participate in group discussions or collaborative sessions hosted within the group.

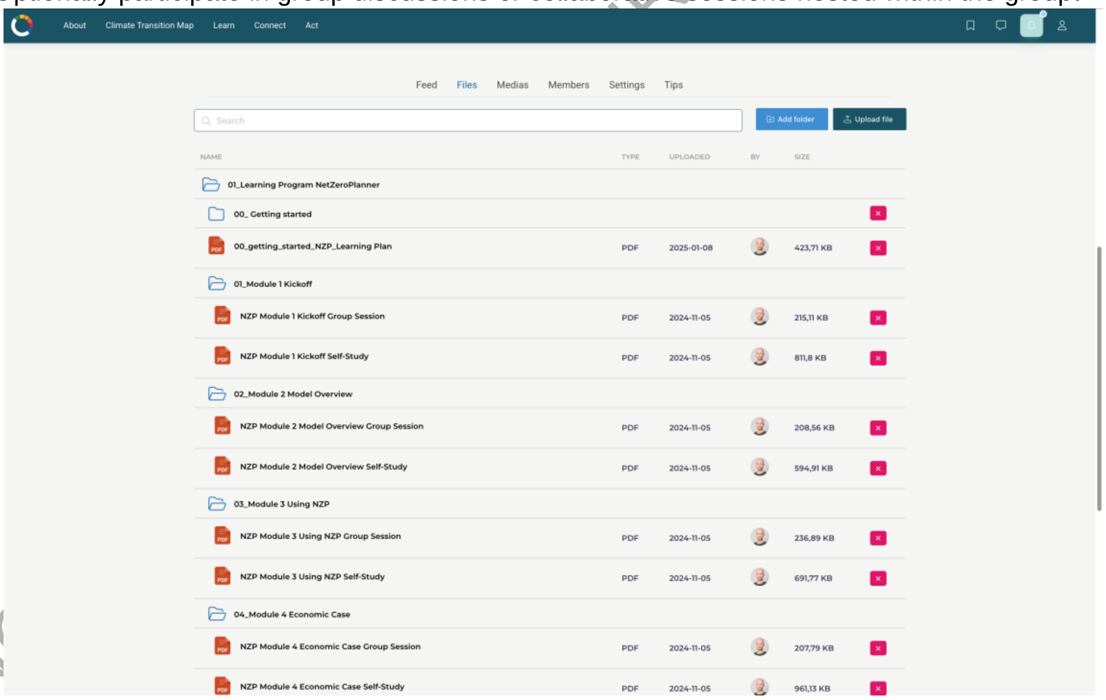

Figure 3. Learning material page in five learning modules.

The Learning Programme acts as a modular and flexible pathway, helping cities build the knowledge, skills, and collaborative capacity to effectively plan and iterate their climate strategies.

Through the group, cities can engage in a reflective and action-oriented learning process – combining technical guidance with peer exchange and local adaptation. This approach directly supports the principles of the Learning Journey outlined in NZC D3.2: encouraging continuous learning, connecting to cities' existing efforts, and fostering change through collaborative action.

Resources for Advanced Users

NetZeroPlanner users come from diverse backgrounds and possess varying levels of expertise in modelling in general, in modelling using this specific tool, and in working within a context of energy, climate and financial and economic analysis. To ensure an inclusive and effective user experience, we strive to balance the needs of less experienced users - who require clear, accessible guidance to quickly engage with the model - with those of more advanced users, who seek detailed insights into its underlying mechanisms and functionalities.

To address these different requirements, we have separated the more basic operating guidance from the deep dives into model specifications and technical aspects. We have developed three technical annexes, each designed to cover distinct aspects of the model. These technical annexes serve as comprehensive resources for users wishing to deepen their understanding of the model's structure, methodologies, and key assumptions. By structuring the guidance in this way, we provide an accessible entry point for new users while simultaneously offering advanced users the technical depth they need to fully leverage the tool's capabilities. This approach ensures that all users, regardless of experience level, can efficiently navigate the user guidance and apply the model in a way that best suits their needs.

Technical Annex 1: Model structure and assumptions explains the structure of the original NetZeroCities economic model and its data points, as well as how reference values for cities are calculated to facilitate the user's input of key data to the model. This annex also provides specific examples of how data points and assumptions are utilised to subsequently produce final outputs such as decarbonisation, economic cases, and co-benefits.

Technical Annex 2: Discount rate in NetZeroPlanner gives an in-depth overview of a particular variable that tends to significantly affect the outcome of economic models, namely that of the discount rate. Economic impact assessments involve the challenge of costs and benefits being distributed over time. The normalising of costs and benefits flows can be done through discounting future costs and benefits to represent a present value, considering the typical assumption that market actors prefer to get one Euro today over one Euro in the future. The discussion on which discount rate to use is well-developed in literature. However, there is no clear answer regarding what the discount rate should be. Given the extended time perspectives in climate investments, the choice of discount rate(s) may have significant implications for the outcome of the analysis. This annex presents a brief overview of the theoretical foundations for choice of discount rate, of some current standards and current debates, and discusses the motivations for the current discount rate in NetZeroPlanner.

Technical Annex 3: FAQ on model-specific details serves as a comprehensive FAQ, addressing key aspects of the model's design, sectoral coverage, data sources, and integration with other climate planning tools.

Summary of Available User Guidance Resources

The user guidance consists of web material and downloadable user guides, each covering different aspects of the model. Table 1 summarises the key components of currently available user guidance.

Table 1. Summary of key learning resources and user guidance

Resource Title	Format	Description
Quick Start Guide	Web site	Brief instructions for getting started
What is NetZeroPlanner?	Web site	Introduction to core functionality and purpose.
NetZeroPlanner walk through	Webinar	Step-by-step demonstration of the tool features
NetZeroPlanner Tutorial – The Economic Case for Decarbonisation	PDF	The document is a tutorial for using the NetZeroPlanner tool, it outlines the tool features and guides the user in running the model.
Learning plan & Kick-offs for group session	PDF	Introduction to the learning programme
Kick-off group session & self study	PDF	Material to kick off self-studies and group studies.
Model overview	PDF	Basic overview of NZP
NetZeroPlanner Methodology	PDF	An overview of methodological design in NZP
Co-benefits for NetZeroCities	PDF	Overview of how co-benefits are integrated into the tool.
Using NZP	PDF	Exercises and information for practical operation of the tool
Economic Case	PDF	A narrative on how the model can be used to demonstrate the economic case for decarbonisation in cities.
Technical Annex 1: Model structure and background assumptions	PDF	Deeper explanation of model structure and assumptions for producing model output.
Technical Annex 2: Discount rate in NetZeroPlanner	PDF	Detailed overview of the reasoning behind the selected discount rate.
Technical Annex 3: FAQ on model-specific details	PDF	FAQ on technical aspects such as model design, data sources, etc.

Concluding remarks

Developing user guidance for NetZeroPlanner has been a structured and iterative process, ensuring that users with varying levels of expertise can effectively navigate and apply the tool. The guidance materials range from introductory resources that help new users get started to in-depth technical annexes designed for advanced users who seek a deeper understanding of the model's structure, methodologies, and assumptions. This tiered approach ensures accessibility while maintaining the necessary technical rigour for more experienced practitioners.

A key takeaway from this process is that user guidance is not static; instead, it evolves in parallel with the model itself and the needs of its users. As cities refine their Climate Action Plans and new modelling challenges arise, ongoing updates and enhancements to both the tool and its guidance will be necessary. The gap analysis conducted between December 2024 and February 2025 exemplifies this adaptive approach, leading to the development of targeted resources that address specific knowledge gaps. Future iterations of user guidance will continue to be shaped by user feedback, ensuring that the materials remain relevant and responsive to emerging requirements.

Furthermore, NetZeroPlanner is designed not only as a modelling tool but also as a learning and decision-support platform. The structured learning modules, self-study materials, and webinars provide a comprehensive framework for capacity building, allowing users to progressively enhance their understanding of climate investment planning. The inclusion of co-benefits, discount rate analysis, and sectoral assumptions in the advanced resources reflects the growing complexity of climate finance and policy considerations that cities must navigate.

As we look ahead, the continuous refinement of both the model and its user guidance will be essential in supporting cities on their path to climate neutrality. By maintaining a balance between usability and analytical depth, NetZeroPlanner is a robust tool for strategic planning, investment prioritisation, and informed decision-making in urban climate transitions. A concrete next step in this development will be D1.8, the assessment of the economic model and updated user guide. We foresee that the user guide update will consist of further structuring of the existing material, further refinement of descriptions of model details, adaptations to new or updated model functionalities, and the uptake of new input from users.

NetZeroPlanner Technical Annex 1: Model Structure and Assumptions

Items

1 Introduction

This document gives a deeper insight into key assumptions and data that NetZeroPlanner (NZP) uses for its calculations, and that are not generally adjustable by the user. The review focuses on the functions of assumptions. Several cases of the climate transition and calculation logic are taken as examples. The first introduces the model structure and the assumptions across the sectors and subsectors (levers). This is followed by a case study on electric vehicle charging infrastructure. Next, the assumptions around the cost of building renovations are highlighted, followed by the methods used for comparable city values' calculations.

NZP attempts to estimate greenhouse gases (GHGs) reductions associated with a range of measures but also to align this with the economic cost and benefits of doing so. Some of these data points are required from the user or are derived from their responses. Other data points are important to the functioning of the model but are not easily accessible or changeable. Some of these are themselves based on assumptions or calculations that are even more hidden and will, in turn, be based on their own range of inputs, simplifications and assumptions. Here, we go through a few of these data points to illustrate how these processes work, and the extent to which changes to their values alter the results generated by the model. This is most clearly the case with the mathematical equations used, for instance, by assuming that two variables are linearly correlated across all possible values when the reality might be more complex. Here we define a three-level hierarchy of assumptions and inputs in the model:

1. Base assumptions – these are the inputs adjustable by a user. Examples could be the city population or the electricity emission factor. Although the tool can give representative values for these, for instance through the comparable city values, they can also be adjusted by the user. These correspond to 199 assumptions in the “data collection” and “future assumptions” in NZP.
2. Hidden assumptions – these are values or assumptions that cannot be changed by a user, and may be entirely hidden within the model, but which nonetheless take a defined value. An example could be the cost of installing rooftop photovoltaic systems. The tool also has baseline values for these assumptions, and they are not within the base assumptions that can be defined by the user.
3. Implicit assumptions - these are assumptions that are not defined within the model but are nonetheless required. Such assumptions could include decisions about the equations used. An example could be that the cost of installing rooftop solar does not vary per country, which is a necessary assumption to include this cost in the model as a single value for all countries. Hence, implicit assumptions are those that occur outside of the model boundary.

In NZP, assumptions are also categorised based on the city's main GHG emission sectors, which are divided into transportation (further split into passenger and freight transport), buildings and heating, electricity, waste management, and others (including IPPU and agriculture). Within the five major sectors, there are 13 subsectors (also referred to as levers or future assumptions), representing the transition from Business-As-Usual (BAU) to the expected targets set by the action plan. The model structure illustrating the relationships between sectors, levers, and assumptions is shown in the diagram below (Figure 4). You can explore the fundamental components of NZP in Module 2: Model Overview of the Learning Journey.

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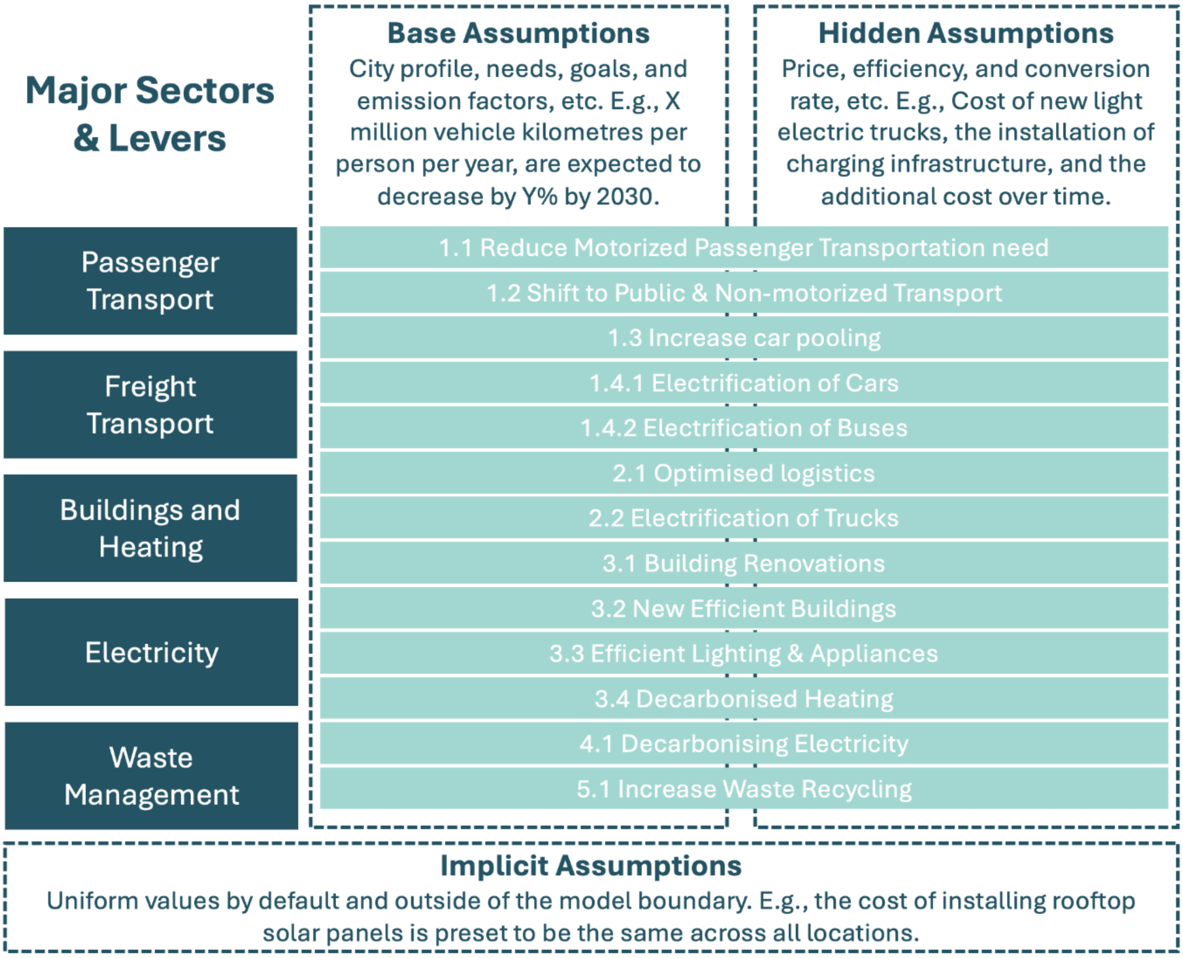

Figure 4. Structure of model sectors and assumptions

2 Assumptions across sectors and levers

Measuring the effectiveness of decarbonisation of the transport sector is one of the key functions of NZP. There are six sets of levers involving 65 base and future assumptions used to calculate the impact of these actions in transport. However, the relationships between these sectors and levers are often interconnected. Here, an overview uses the lever of '1.4.2: Electrification of Public Bus Transport' as an example to illustrate the assumptions involved in this lever and the assumptions referenced from other levers.

Base assumptions in this lever, such as current bus demand (Million passenger-kilometers per year) and future electrification targets (as percentages over time) from data collections and future assumptions pages are the major assumptions for calculating the lever's effort. Additionally, related levers, such as '1.1: for Reducing Overall Reliance on Motorised Vehicles' or '1.2: Shifting from Motorised Vehicles to Public Transport', will gradually decrease overall transportation demand over time. This reduction leads to lower operational costs, fewer traffic-related accidents, and decreased emissions and pollution, which affects the lever of 1.4.2. The calculations for these effects involve multiple actions, which are marked in the diagram below (Figure 5).

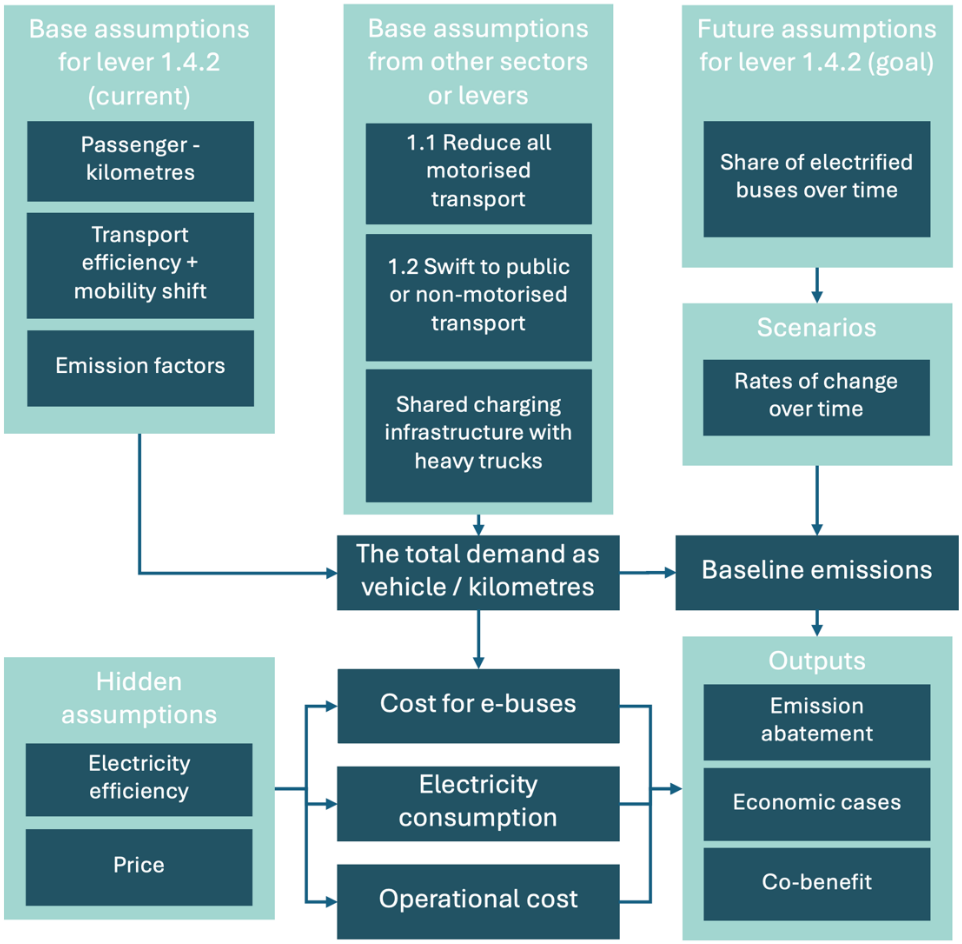

Figure 5. Interconnection of assumptions in lever 1.4.2.

NZP further converts assumptions into emission calculation units, aligning them with the emission factors used. For example, it transforms annual transportation demand per million passenger kilometres into emissions per unit of vehicle kilometres. The calculation process starts as shown in the top-left boxes 'Base assumptions for lever 1.4.2' and 'Base assumptions from other sectors or levers' of Figure 5 by determining the total human mobility demand for a city. This demand is then converted into the required vehicle kilometres travelled based on the capacity of each transport mode (how many passengers can one bus serve in general). Since emissions are calculated at the vehicle level, this step is necessary to apply emission factors for each transport mode and estimate the resulting emissions based on the given demand.

Future assumptions and scenario values serve as the basis for emission reduction estimates, considering the annual targets set for each action and the rate of change resulting from each action. The impact of other actions, such as reducing total motorised transport demand, leads to lower public transport demand and a shift from private vehicles to public transport, where car usage is converted into an equivalent demand for public transport, which is then factored into annual forecasts.

This case illustrates how assumptions from different sectors are referenced within the model to complete the calculations. At the same time, NZP calculations involve multiplying types of assumptions such as unit, quantity, conversion factor, and weight. This ensures consistency across all sectors, allowing the model to assess the impact of individual actions or sub-sectors in terms of emissions, costs, and co-benefits.

Next, we will use two case studies to illustrate the calculation process of different types of assumptions within individual levers.

2.1 Assumptions About the Infrastructure Cost of Automobile Electrification

A key determinant of a city's success in reaching climate neutrality is the decarbonisation of transport. The transition to electric vehicles is widely seen as crucial in this regard. However, the associated cost of this, as well as how it is distributed between stakeholders, is still an area of debate.

The model includes a lever labelled '1.4.1: Electrification of Cars' for the transition to electric cars. This lever operates by first determining the number of cars to be electrified each year, which is based on two inputs: the number of cars in the city and the annual electrification rate (as a percentage). Over time, this leads to an increase in the share of total electric cars in the city.

Each new electric car incurs an associated infrastructure cost in the model. This includes costs for electric cars and charging (at-home chargers as well as public and commercial chargers). Here, there is already an implicit assumption that the number of both charger types is linearly correlated with the number of cars. This may not be the case in reality – the number of public chargers may saturate at high electric car shares, for instance – but is likely a reasonable step to take.

Determining assumption values

The model assigns fixed cost values for vehicle charging infrastructure: € 458 per electric vehicle for private (home) chargers and € 407 per vehicle for public or workplace chargers. These values are not adjustable in NZP. Both are based on a study from 2019 on estimating vehicle charging infrastructure costs across major US metropolitan areas (Nicholas, 2019). These values are applied uniformly across all countries and cities, including those who have provided context-specific data

The model further assumes that these infrastructure costs will decrease annually by 0.8 % for private chargers and 6.5 % for public chargers, based on projections from the same study. Since the original cost values are in U.S. dollars, they are converted to euros using a fixed exchange rate of 0.85 €/$. This exchange rate remains constant over time, reflecting an implicit assumption that technology costs are the same in the United States and Europe. Notably, the conversion rate itself is also a static parameter that cannot be adjusted in NZP.

It should be hence acknowledged that a number of assumptions have shaped the cost values used in the model. Charging infrastructure costs are generally known to be heterogeneous across countries and regions (Lanz, 2022), which may impact the accuracy of applying uniform values across cities as NZP does.

Assumption in the Model

The model adds the estimated costs for private and public chargers to calculate the total infrastructure cost per electric vehicle. It multiplies this with the number of new electric cars added to the model each year, generating the total infrastructure costs for that year. This total is added to the up-front purchase costs of the electric vehicles (although with different assumed distributions between stakeholders) to obtain the total costs per year for the transition to electrification of vehicles. The resulting total costs subsequently feed into the lever's net present value (NPV) calculation.

The cost of electric cars is an assumption in the model that is difficult to estimate. The model assumes a single, uniform value for the additional cost of electric vehicles across all countries with a fixed amount of € 8,602 per electric vehicle, derived from the same study (Nicholas 2019). This processing path through the model´s calculations as the infrastructure cost (Figure 6).

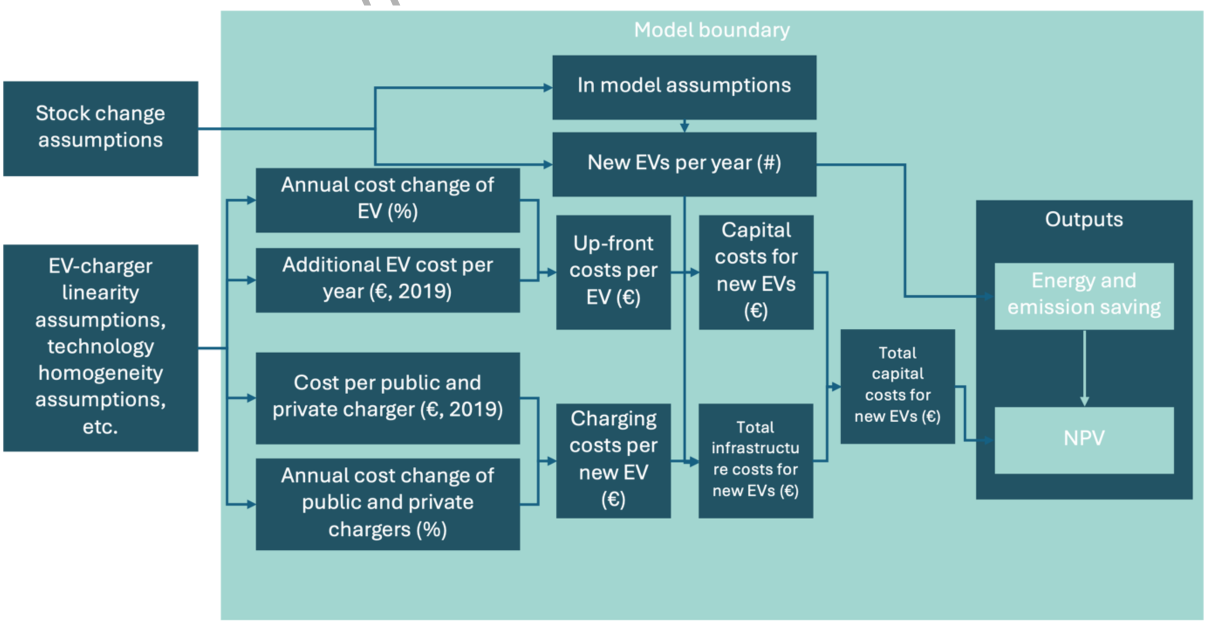

Figure 6. Conceptual flow of EV investment cost assumptions in lever 1.4.1.

Assumption Sensitivity

Given the number of assumptions and simplifications underlying the calculation of infrastructure costs, it is helpful to investigate their importance in the model through sensitivity analysis. To illustrate, we assess how the outputs of the model adjust to a hypothetical doubling of the initial cost values.

If we double the infrastructure cost, the total business case for the electrification of vehicles changes from € -30.4 million (NPV) to € -49.8 million (NPV), reflecting a cost increase of around 60 %.

On the other hand, doubling the assumed cost of electric vehicles changes the business case to a final value of € -60.4 million (NPV), essentially a doubling of the initial costs. These numbers are illustrative and may vary depending on the initial assumptions provided by each city. Nonetheless, they do show that the charging infrastructure costs are an important assumption in the model (albeit less impactful than the price of electric vehicles) and may benefit from a revision that reflects the cost variations observed across Europe in future upgrades of the model.

2.2 Assumptions About the Cost of Renovating Buildings

A second series of assumptions relate to the way the model processes building renovation costs (lever '3.1.1: Building Renovations'). Building renovation reduces energy use and costs for inhabitants, which should lead to environmental and economic savings over time. However, it will incur some upfront costs. Building renovation is an independent lever in the model.

Determining Assumption Values

The key input data users can enter is the building renovation rate (as a percentage) and the breakdown of renovation into minor and extensive renovations. It is assumed that minor renovations reduce energy use by 15%, and extensive renovation by 45%. While users can adjust the renovation rates as the goal of action 3.1, the energy-saving assumptions are hidden and cannot be modified. This distinction is important, as it affects how flexible the model is in reflecting real-world variations in renovation outcomes.

The values of 15 % and 45 % are derived from a 2016 study (Artola et al., 2016), which in turn references a 2011 report by the Buildings Performance Institute Europe (BPIE) (Economidou, 2011). This report classifies renovations into four categories: minor, moderate, extensive and nearly zero-energy building renovations, with corresponding. These have associated energy saving ranges of 0-30 %, 30 – 60 %, 60 – 90 % and 95 %. NZP assumes that the central values reflect the average level of energy savings achieved by each category. Hence, the model´s "extensive" renovation category aligns with the energy-savings of the "moderate" category in the BPIE definitions. Users with detailed knowledge of the building renovation technology may be able to adjust the inputs to account for the mismatch, but the results may be misleading due to discrepancies between the definitions of NZP and the original studies. This discrepancy may exist in the hidden assumptions. Since users cannot directly view these assumptions, errors can be difficult to detect.

Simplifying the renovation type into two categories (minor and extensive) also includes other implicit assumptions. One assumption is that energy savings will align with the average values of the BPIE categories or that the distribution of savings within each category will be symmetric. However, if these categories were to correspond to BPIE categories, it might be the case that most buildings would only achieve the minimum energy savings required to fit into each category rather than the average. Additionally, the default share of minor and extensive renovations in the model is 50 % each (against a baseline of 85 % of renovations being minor in the model)., but in NZP, they default to the comparable city values.

Also, the default renovation rates for cities' building stock are derived from comparable city values (see section 3 of this annex). For example, the baseline scenario values are 1.15 %, with a decarbonisation value of 2.96 % for a cold city with a high renewable share. An implicit assumption is that buildings can only be renovated once and a building that has undergone minor renovations cannot then be renovated again. While this is unlikely to be a problem for Mission Cities considering a 2030 timespan, it could become more problematic for cities looking at an extended planning interval such as 2050.

Turning to cost estimates, the model assumes that the cost of minor renovation is € 57 per m2 and for extensive renovations is € 125 per m2. These assumptions cannot be adjusted by the user, hence are hidden assumptions. However, as some cities have collected these data, they could be adjusted using the comparable city values calculation.

Additionally, among the model's assumptions, there is a cost projection for the years 2018 – 2040. It is unclear how this has been derived. Year-to-year differences in this projection are used to determine annual cost changes. However, these have been modified based on conversations with industry experts. As a result of these discussions, the model assumes a default cost improvement of 0 % per year for light renovations and 1 % per year for extensive renovations. Since these are predefined values that users can´t change, they are hidden assumptions.

As these values are not adjusted based on differences in climate, building type and qualities, the model assumes the cost of renovation is independent of context and climatic conditions. Similarly, it assumes that the cost is independent of the original energy efficiency of the building. In reality, it might become progressively more expensive to renovate buildings based on their initial efficiency.

Assumption in the Model

The model calculates energy use in buildings by requiring the user to enter the annual building heating energy demand in units of GWh per year, and the size of the building stock to derive energy use per m2. The baseline value is then adjusted according to the assumed energy savings for each renovation type (for example, 15% for minor renovations and 45% for extensive ones) Based on the renovation rate and the minor/extensive renovations shares, it then calculates the annual upfront cost and energy use in all three types of existing buildings (unrenovated, minor renovations, and extensive renovations).

The cost of achieving the necessary level of renovation is determined by the total expenses, including both minor and extensive renovations in the decarbonisation scenario compared to the baseline. This cost difference is essential for calculating economic utility measures, such as NPV, as well as assessing co-benefits, like the number of jobs created. These factors, in turn, depend on various hidden and implicit assumptions, including the distribution of costs and benefits among stakeholders and the number of jobs generated, which is estimated at 18 jobs per million euros (Cuchi and Sweatman, 2011).

Thus, the initial assumption travels through the model as follows in Figure 7:

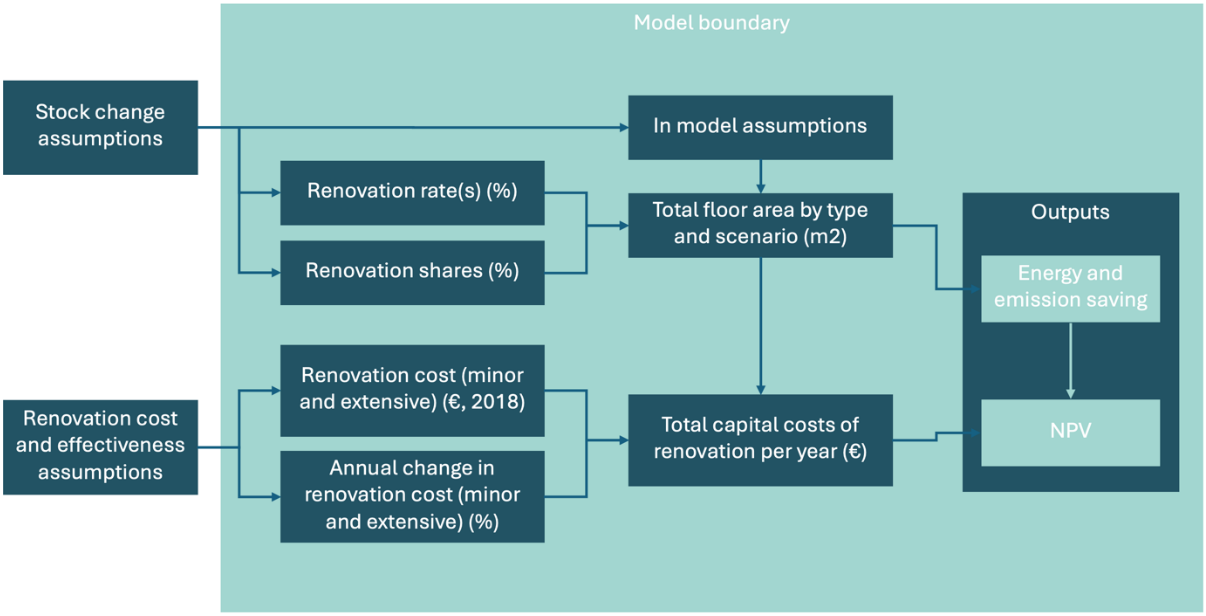

Figure 7. Conceptual flow of building renovation cost assumptions in lever 3.1.1.

Assumption Sensitivity

The question of the sensitivity to these assumptions is approached in the same way as for EV infrastructure costs. Based on the same initial model parameters, an illustrative initial NPV by 2030 for building renovations was € 869.0 Million (NPV). Doubling the renovation costs increases this to € 1956.6 Million (NPV), effectively doubling of the costs. As a point of comparison, if the efficiency improvements are doubled (to 30 % and 90 %, respectively), the costs are reduced to € 630.3 Million (NPV)

3 Assumptions About Comparable City Values

For cities developing new climate action plans, NZP provides a user-friendly feature called 'Comparable City Values', allowing cities to quickly obtain reference input values if exact city data is not available. This section explains the factors considered in the calculation of Comparable City Values.

The calculation of Comparable City Values is based on data from 42 Mission Cities that used the original economic model for the development of the Climate City Contract between 2022 and 2024. A classification groups cities into four groups based on annual average temperature and the share of renewable energy in the electricity mix:

1. Cities with an annual average temperature above or below 12°C (warmer or cooler).
2. Cities where the proportion of renewable energy and nuclear power in the electricity mix is high or low.

This is a simplified classification system designed to quickly match cities with similar characteristics in emissions, using data from similar cities as a reference. These four groups of cities are listed as below table 1.

Table 1. City groups based on temperature and energy mix.

Group	Cities
Cooler and a lower share of renewable energy and nuclear power.	Aachen, Amsterdam, Heidelberg, Krakow, Ljubljana, Muenster, Rzeszow, Sophia, Vilnius, Wroclaw
Warmer and a lower share of renewable energy and nuclear power.	Athens, Florence, Guimaraes, Limassol, Lisbon, Porto, Thessaloniki, Trikala
Cooler and a higher share of renewable energy and nuclear power.	Angers Loire, Bratislava, Budapest, Dunkirk, Gothenburg, Grenoble Alpes, Kosice, Lund, Miskolc, Pecs, Reykjavik, Stavanger, Trondheim
Warmer and a higher share of renewable energy and nuclear power.	Barcelona, Bordeaux, Lyon, Madrid, Nantes, Paris, Seville, Valencia, Valladolid, Vitoria-Gasteiz, Zaragoza

The calculation for the Comparable City Values with population-weighting

For some base assumptions, the population is used to scale the values for each city within a comparable city group. The diagrams below illustrate the relationship between the population-weighted estimated values and the simple average values within the given data distribution in one example city group.

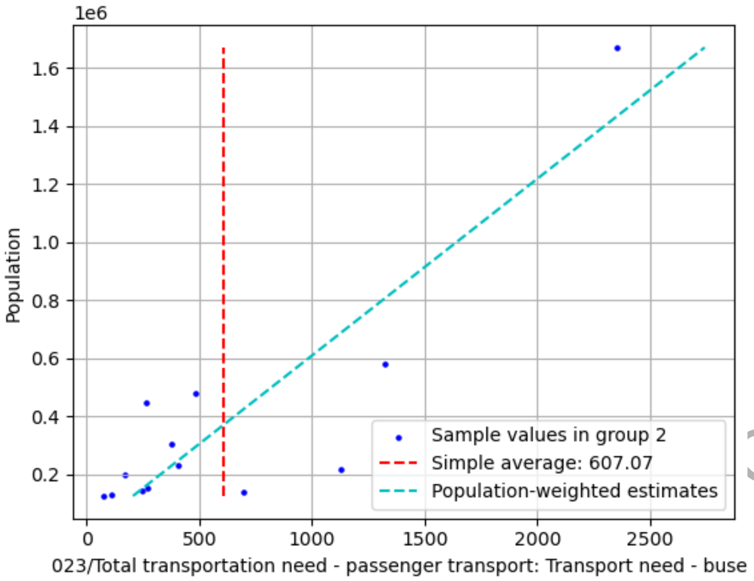

Figure 8. Comparing methods for a population-driven assumption: the need for buses.

In this example, the assumption used is the total bus demand among cities in a given city group. The cyan line in Figure 8 represents the population-weighted estimate, while the red line represents the simple average of the dataset. Since bus demand within a city is closely driven by its population, a positive correlation between population size and bus demand is based on the data distribution. In this case, the cyan line reflects the estimates more appropriately. The population entered by a city when creating a new plan in NZP serves as a scaling factor in the estimation for this type of assumption. The base assumptions using this population-weighted method are listed in the table in Appendix 1.

The relationship between the types of assumptions and population determines the calculation formula for Comparable City Values, as is shown in the equation below, where N is the number of cities within the same group, V(x) is the target estimate of one given assumption, V(m) is the value for the given assumption from city M within the group, P(m) is the size of the population of city M within the group, the mean of V(m) was divided by the mean of P(m) and multiplied by P(x) which is the size of the population of the target city X (Equation 1).

$$V(x) = \frac{\frac{1}{n}\sum_1^n \quad V(m)}{\frac{1}{n}\sum_1^n \quad P(m)} \times P(x)$$

Equation 1. Calculation based on population.

At the same time, for another assumption in the transportation sector, the correlation between the average passenger capacity of transport vehicles and population is less significant. From the data distribution shown below Figure 9, the distribution of values for this assumption remains relatively consistent across cities. In this case, the simple average (red line) can better represent the estimated results, as the red line shows.

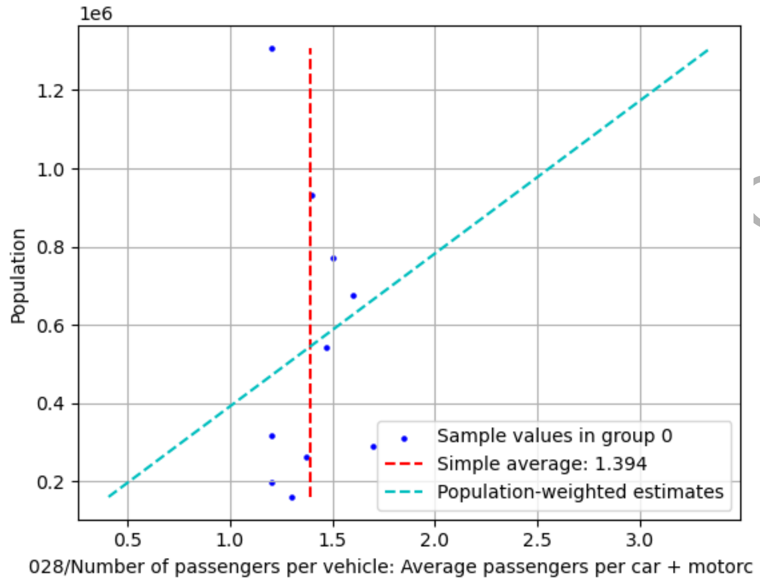

Figure 9. Comparing methods for a non-population-driven assumption: the number of passengers served by a car or motorcycle.

These assumptions are not related to the population, the simple average value of the group is used (Equation 2). Full list for this group is in the table of Appendix 2.

$$V(x) = \frac{1}{n}\sum_{1}^{n} V(m)$$

Equation 2. Calculation based on average.

The Limitations for Grouping Criteria

The purpose of grouping cities is to allow new cities to refer to the base assumptions of similar cities when developing their action plans. However, the methodology behind Comparable City Values carries certain implicit assumptions, which stem from data availability constraints and methodological simplifications.

For the criteria of warm or cold – Since cities measure annual average temperature using different ranges and methods, and no reliable dataset collects yearly average temperatures for all cities, the model adopted a simplified approach. Using 2022 European average heating and cooling demand days as a proxy, the model set the European average temperature for that year as the baseline. Then, the model adjusted this baseline by comparing the heating or cooling demand days of the NUTS3 regions where reference cities are located against the European average, refining it to a 12°C baseline.

Simplification vs. Accuracy Trade-off – Using the classification criteria of relatively warm or cold conditions is intended to provide an intuitive way to reflect a city's energy and heating demands. This method reduces complex calculations for city users, requiring only a rough classification of whether a city’s annual average temperature is above or below the baseline. However, generalising temperature data in this way fails to capture large seasonal temperature variations that may exist in some cities. Cities with larger seasonal temperature variations may have higher heating or cooling demands compared to cities with more moderate temperature changes. Using average temperature alone cannot fully capture the characteristics of such cities. As a result, Comparable City Values may underestimate key assumptions for the building and electricity sectors in these cities.

Impact of climate variability – Since the method is based on 2022 average temperatures, if a given year experiences anomalously warm or cold conditions, the reference values may not accurately reflect the city's actual climate conditions when developing a new plan.

Potential sampling bias: Since cities within the same country often share similar energy compositions and climate conditions, having multiple cities from the same country in the sample can disproportionately influence the Comparable City Values. As a result, with a limited sample size, the methodology may not reflect key assumptions properly for countries with fewer sampled cities, leading to greater deviations for those cities.

4 Concluding Remarks

This review focuses on describing the ways that the model has incorporated certain assumptions that are critical for the costs of transition, whilst being concurrently difficult to estimate and not easily accessible to the user; the costs of electric car charging infrastructure and building renovations. Transport and building energy are arguably the two most important sectors for city decarbonisation. This notwithstanding, the two values were chosen simply to illustrate how the model is based on different levels of assumptions that sit both inside and outside the formal model and may or may not be adjustable. Similar analysis could be performed for a wide range of further assumptions and inputs in the tool. Doing so has not been with the intention of pointing out weaknesses or problematic areas. But all models are simplifications of more complex phenomena. Highlighting the consequences of this is important not only for common interest and increasing transparency, but also for guiding how methodological developments can best serve the intended use of NZP.

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6 Appendix

Appendix 1: Table of population-weight base assumptions

Sector	Base Assumptions
Passenger Transport	• Transport need - passenger cars + motorcycles • Transport need – buses • Transport need - trains/metro • Transport need - walking/cycling • Total number of cars motorcycles in city • Number of buses in city bus fleet
Freight Transport	• Transport need - Light duty trucks <3.5 tonnes • Transport need - Heavy duty trucks >3.5 tonnes • Number of trucks registered within city: Light duty trucks <3.5 tonnes • Number of trucks registered within city: Heavy duty trucks >3.5 tonnes
Buildings and Heating	• Existing building stock: Total floor area (residential & non-residential) • Total heating demand (space heating + domestic hot water)
Electricity	• Total electricity demand within city boundaries
Waste Management	• Total collected waste within city boundaries: Paper and cardboard • Total collected waste within city boundaries: Metal • Total collected waste within city boundaries: Plastics • Total collected waste within city boundaries: Glass • Total collected waste within city boundaries: Organic waste • Total collected waste within city boundaries: Other waste (e.g. textiles, rubble, wood etc)
Greenhouse Gases	• Greenhouse gases (CO2 emissions other greenhouse gases) of Total emissions (scope 1 & scope 2; scope 3 only for waste disposed of outside city boundaries) • Greenhouse gases (CO2 emissions other greenhouse gases) of Emissions from road transportation: Total emissions from road transport • Greenhouse gases (CO2 emissions other greenhouse gases) of Emissions from road transportation: Passenger cars + motorcycles • Greenhouse gases (CO2 emissions other greenhouse gases) of Emissions from road transportation: Light duty trucks <3.5 tonne • Greenhouse gases (CO2 emissions other greenhouse gases) of Emissions from road transportation: Heavy duty trucks >3.5 tonne

	• Greenhouse gases (CO2 emissions other greenhouse gases) of Emissions from road transportation: Buses • Greenhouse gases (CO2 emissions other greenhouse gases) of Emissions from road transportation: Other motorized transport • Greenhouse gases (CO2 emissions other greenhouse gases) of Emissions from buildings & heating: Heating & hot water • Greenhouse gases (CO2 emissions other greenhouse gases) of Emissions from buildings & heating: Cooling • Greenhouse gases (CO2 emissions other greenhouse gases) of Emissions from buildings & heating: Other building-related emissions • Greenhouse gases (CO2 emissions other greenhouse gases) of Emissions from electricity: Total emissions from electricity demand • Greenhouse gases (CO2 emissions other greenhouse gases) of Emissions from electricity: Buildings • Greenhouse gases (CO2 emissions other greenhouse gases) of Emissions from electricity: Other • Greenhouse gases (CO2 emissions other greenhouse gases) of Emissions from waste (including waste disposed of outside of city boundaries): Incineration of waste • Greenhouse gases (CO2 emissions other greenhouse gases) of Emissions from waste (including waste disposed of outside of city boundaries): Organic decay (waste) • Greenhouse gases (CO2 emissions other greenhouse gases) of Emissions from waste (including waste disposed of outside of city boundaries): Landfill gas • Greenhouse gases (CO2 emissions other greenhouse gases) of Emissions from waste (including waste disposed of outside of city boundaries): Other waste management • Greenhouse gases (CO2 emissions other greenhouse gases) of Emissions from other sectors: Industry • Greenhouse gases (CO2 emissions other greenhouse gases) of Emissions from other sectors: Agriculture • Greenhouse gases (CO2 emissions other greenhouse gases) of Emissions from other sectors: Other sources

Appendix 2: Table of non-population-weight base assumptions

Sector	Base Assumptions
City profile	• Population • Expected annual population growth (up until 2030) • City Area
Passenger Transport	• Number of passengers per vehicle: Average passengers per car + motorcycle • Number of passengers per vehicle: Average passengers per bus • Number of passengers per vehicle: Average passengers per metro train • Emission factors of Passenger car motorcycle fleet (current average fleet): CO_2 emissions • Emission factors of Passenger car motorcycle fleet (current average fleet): NO_x emissions • Emission factors of Passenger car motorcycle fleet (current average fleet): PM 2.5 emissions • Emission factors of Passenger car motorcycle fleet (current average fleet): PM 10 emissions • Buses (average fleet): CO_2 emissions • Buses (average fleet): NO_x emissions • Buses (average fleet): PM 2.5 emissions • Buses (average fleet): PM 10 emissions • Share of fleet that is less than 2 years old • Share of fleet fully electric (not including hybrids) • Share of bus fleet as fully electric buses (not including hybrids) • Share of bus fleet - biobased
Freight Transport	• Average utilisation: Light duty trucks <3.5 tonnes • Average utilisation: Heavy duty trucks >3.5 tonnes • Emission factors from transportation for Light duty trucks <3.5 tonnes: CO_2 emissions • Emission factors from transportation for Light duty trucks <3.5 tonnes: NO_x emissions • Emission factors from transportation for Light duty trucks <3.5 tonnes: PM 2.5 emissions • Emission factors from transportation for Light duty trucks <3.5 tonnes: PM 10 emissions • Emission factors from transportation for Heavy duty trucks >3.5 tonnes: CO_2 emissions • Emission factors from transportation for Heavy duty trucks >3.5 tonnes: NO_x emissions • Emission factors from transportation for Heavy duty trucks >3.5 tonnes: PM 2.5 emissions • Emission factors from transportation for Heavy duty trucks >3.5 tonnes: PM 10 emissions • Number of trucks registered within city: Of which less than 2 years old

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	• Number of trucks registered within city: Of which less than 2 years old
Buildings and Heating	• Average heat use in existing buildings (space heating + domestic hot water) • Average electricity use for lighting & appliances • Share of building stock renovated each year • Energy efficiency improvements from building renovations: Minor heating renovations (0-30% improvement) • Energy efficiency improvements from building renovations: Extensive heating renovations (30-60% improvement) • Cost of energy renovations: Minor heating renovations (0-30% improvement) • Cost of energy renovations: Extensive heating renovations (30-60% improvement) • Building standards for new buildings: Minimum building standard (heat use) • Building standards for new buildings: Top performing building standard (heat use) • Share of new buildings built with minimum standard (today) • Share of new buildings built with "better than minimum" standard (today) • Building costs - new buildings: Minimum building standard • Building costs - new buildings: Top performing building standard • Share of heating as district heating • Share of heating as local heating • Share of district heating as Fossil (oil, coal, gas) + inefficient electric heating (not heat pumps) • Share of district heating as Electric heat pumps / geothermal • Share of district heating as Bio (biogas, biomass) • Share of district heating as Waste (fossil & non-fossil waste) • Share of waste used in district heating that is fossil / non-fossil: Fossil share • Share of waste used in district heating that is fossil / non-fossil: Non-fossil share • Share of local heating as Fossil (oil, gas, coal) + inefficient electric heating (not heat pumps) • Share of local heating as Electric (heat pumps) • Share of local heating as Biobased • Emission factors from heat production of District heating: CO2 emissions • Emission factors from heat production of District heating: NOx emissions • Emission factors from heat production of District heating: PM 2.5 emissions

	• Emission factors from heat production of District heating: PM 10 emissions • Emission factors from heat production of Local heating: CO2 emissions • Emission factors from heat production of Local heating: NOx emissions • Emission factors from heat production of Local heating: PM 2.5 emissions • Emission factors from heat production of Local heating: PM 10 emissions • Retail price of heating
Electricity	• Share of total electricity demand produced by Renewable sources • Share of total electricity demand produced by Fossil sources • Share of total electricity demand produced by Other (e.g. nuclear) • Emission factors from electricity generation: CO2 emissions • Emission factors from electricity generation: NOx emissions • Emission factors from electricity generation: PM 2.5 emissions • Emission factors from electricity generation: PM 10 emissions • Spot price electricity • Solar electricity produced by solar PVs • Yearly average of solar electricity generated by 1 m2 solar PV • Retail price of electricity
Waste Management	• Total collected waste within city boundaries • Share of paper waste - other (e.g. landfilled) • Share of paper waste - incinerated (e.g. energy recovery) • Share of paper waste – recycled • Share of metal waste – landfilled • Share of metal waste - incinerated (e.g. energy recovery) • Share of metal waste – recycled • Share of plastic waste – landfilled • Share of plastic waste - incinerated (e.g. energy recovery) • Share of plastic waste – recycled • Share of glass waste – landfilled • Share of glass waste - incinerated (e.g. energy recovery) • Share of glass waste – recycled • Share of organic waste – landfilled • Share of organic waste - incinerated (e.g. energy recovery)

	• Share of organic waste – composted • Share of "other" waste – landfilled • Share of "other" waste - incinerated (e.g. energy recovery) • Share of "other" waste – recycled • Emission factors from waste management of Incineration: CO2 emissions • Emission factors from waste management of Incineration: NOx emissions • Emission factors from waste management of Incineration: PM 2.5 emissions • Emission factors from waste management of Incineration: PM 10 emissions
Levers in Passenger Transport	1.1 Reduced motorised passenger transportation need • Transportation need reduction by 2030 from urban planning, digital meetings and other transport-reducing initiatives 1.2 Shift to public and non-motorised transport • Reduced passenger kilometres by car through shift to public and non-motorised transport/Reduced P-km cars + motorcycles by 2030 • Share of car + motorcycle km reduced shifted towards Buses • Share of car + motorcycle km reduced shifted towards Trains/metro • Share of car + motorcycle km reduced shifted towards Walking/cycling 1.3 Increased car pooling • Percentage increase in avg. passengers per car + motorcycles (2030) due to improved transport efficiency from better Car pooling and Mobility as a Service 1.4.1 Electrification of passenger cars • What is the maximum share of the passenger car + motorcycle fleet that can be electrified? • At what year can we expect the city to reach the maximum value specified above? 1.4.2 Electrification of buses • Expected procurement schedule for buses/2020 • Expected procurement schedule for buses/2021 • Expected procurement schedule for buses/2022 • Expected procurement schedule for buses/2023 • Expected procurement schedule for buses/2024 • Expected procurement schedule for buses/2025 • Expected procurement schedule for buses/2026 • Expected procurement schedule for buses/2027

	• Expected procurement schedule for buses/2028 • Expected procurement schedule for buses/2029 • Expected procurement schedule for buses/2030
Levers in Freight Transport	2.1 Optimisation of logistics • Utilisation of trucks in decarbonisation scenario/Light duty trucks • Utilisation of trucks in decarbonisation scenario/Heavy duty trucks • Utilisation of trucks in decarbonisation scenario/Reduction of total distance travelled through route optimisation 2.2 Electrification of trucks • Light duty trucks <3.5 tonne/What is the maximum share of the truck fleet that can be electrified? • Light duty trucks <3.5 tonne/At what year can we expect the city to reach the maximum value specified above? • Heavy duty trucks >3.5 tonne/What is the maximum share of the truck fleet that can be electrified? • Heavy duty trucks >3.5 tonne/At what year can we expect the city to reach the maximum value specified above?
Levers in Buildings and Heating	3.1 Buildings renovations • Renovation rate - decarbonisation scenario • Assumed share of type of renovation in lever/Minor heating renovations (0-30% improvement) • Assumed share of type of renovation in lever/Extensive heating renovations (30-60% improvement) 3.2 Energy efficient new buildings • Improvement in energy efficiency relative to minimum requirement • Share of new buildings built with high energy efficiency standards/Minimum building standard • Share of new buildings built with high energy efficiency standards/Top performing building standard 3.3 Efficient lighting & appliances • Renovation rate - decarbonisation scenario • Assumed share of type of efficiency programme for lever/Minor efficiency improvements for lighting and appliances (~15%) • Assumed share of type of efficiency programme for lever/Aggressive efficiency improvements for lighting and appliances (~40%)

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	3.4 Decarbonising heating • Share of heating as district heating, 2030 • Share of heating as local heating, 2030 • Share of district heating in 2030 as/Fossil (oil, coal, gas) + inefficient electric heating (not heat pumps) • Share of district heating in 2030 as/Electric heat pumps / geothermal • Share of district heating in 2030 as/Bio (biogas, biomass) • Share of district heating in 2030 as/Waste (fossil & non-fossil waste) • Share of waste in 2030 used in district heating that is fossil • Share of waste in 2030 used in district heating that is non-fossil • Share of local heating in 2030 as/Fossil (oil, coal, gas) + inefficient electric heating (not heat pumps) • Share of local heating in 2030 as/Electric (heat pumps) • Share of local heating in 2030 as/Bio-based • Share of current fossil production that would need to be re-invested in by 2030, if current production where to continue for District • Share of current fossil production that would need to be re-invested in by 2030, if current production where to continue for Local heating
Levers in Electricity	4.1 Decarbonising electricity • Share of current fossil production replaced by renewables • Local solar PV (e.g. rooftops) • Centralised Solar PV/wind farms
Levers in Waste Management	5.1. Increased recycling of waste • Treatment of paper, 2030/Landfill • Treatment of paper, 2030/Incineration • Treatment of paper, 2030/Recycling • Treatment of metals, 2030/Landfill • Treatment of metals, 2030/Incineration • Treatment of metals, 2030/Recycling • Treatment of plastics, 2030/Landfill • Treatment of plastics, 2030/Incineration • Treatment of plastics, 2030/Recycling • Treatment of glass, 2030/Landfill • Treatment of glass, 2030/Incineration • Treatment of glass, 2030/Recycling • Treatment of organic, 2030/Landfill • Treatment of organic, 2030/Incineration • Treatment of organic, 2030/Composting

Other Lever	• Percentage CO_2e reduction by 2030 in other sectors

NetZeroPlanner Technical Annex 2: Discounting in NetZeroPlanner

Items

1 Background

Economic impact assessments involve the challenge of costs and benefits being distributed over time. The normalising of costs and benefits flows can be done through discounting future costs and benefits to represent a present value (PV), considering the typical assumption that market actors prefer to get one Euro today over one Euro in the future.

The discussion on which discount rate to use is well-developed in literature. However, there is no clear answer on what the discount rate should be. Given the extended time perspectives in climate investments, the choice of discount rate(s) may have significant implications for the outcome of the analysis. This document thus presents a brief overview of the theoretical foundations for choice of discount rate (Section 2), of some current standards and current debates (Section 3), and discusses the motivations for the current discount rate of 3.5 % in NetZeroPlanner (Section 4).

2 Theoretical Foundation

Calculating PV is a way of transforming future economic flows to their value would they occur today instead. Since economic actors tend to prefer incomes sooner rather than later, a positive interest rate is usually applied in this transformation. Net Present Value (NPV) can be expressed as a function of values of costs (C) or benefits (B), time of their occurrence (t), and the discount rate (r) (eq.1):

$$NPV = \sum_{t=0}^{T} \frac{1}{(1+r)^t}(B_t - C_t) \qquad \text{(eq.1)}$$

Since r is in the denominator of the expression in eq.1, a high r means that the PV of costs and benefits occurring in the future are small, and vice versa for a low r.

The discount rate can be assumed to have two components: the time preference, i.e. the preference for now over later, and the wealth effect, i.e. the suggestion that the utility of consumption decreases as GDP grows. An expression for the discount rate taking these two components into account is the Ramsey formula, below simplified as follows (HM Treasury 2022):

$$r = \rho + \mu g \qquad \text{(eq.2)}$$

Where r is the discount rate, ρ is the time preference and μg is the wealth effect; the per-unit utility of consumption μ multiplied by the expected growth rate of future real per capita consumption g (assumingly GDP per capita).

3 Standards and Examples of Scientific Discourse

The UK green book provides a basis for the Social Time Preference Rate (STPR), which is the discount rate recommended for UK government appraisal in public sector projects. The Green book recommends a discount rate of 3.5 %. The motivation to this figure in the Green Book is a statement that ρ is assumed at 1.5 % (with no particular underpinning), a statement that μ is assumed at 1 (underpinned with literature references – although suggesting somewhat higher values) and a statement that g is 2 % (underpinned with historic annual per capita consumption growth for the UK). An interpretation of the reasons behind these assumptions, including the resulting 3.5% discount rate, could be that the selected discount rate represents a combination of habit and practicality, while; in the absence of empirical evidence, at least not being disproved by literature.

An exception to the standard discount rate of 3.5 % is the Green Book's recommendation for discounting health and life values, which is set to 1.5 %, being motivated by excluding the wealth effect (μg in eq.2) – i.e. the marginal utility value of "consuming" health does not decrease with a generally increased level of (other) consumption.

Moreover, the UK Green Book recommends that the discount rate should decline in the long term due to uncertainty about future values. The discount rate should be set to 3.5 % for years 0-30, 3 % for years 31-75 and 2.5 % for years 76-125. Correspondingly decreasing discount rates should be used for health effects. It can be noted that the relevant time periods in NetZeroPlanner are in the shorter of these intervals.

The discussion on declining discount rates is technical. The reason for using a declining discount rate is related to uncertainty about the future consumption growth (Arrow et al. 2014). However, the US Government instead promotes the use of a constant but lower discount rate for projects that affect future generations.

Among the most prominent discourses in discount rate selection is that of a “descriptive” vs. a “prescriptive” approach, although these terms may be misleading (Baum 2009). A descriptive approach to discounting would match the interest rates observed in financial markets, whereas a prescriptive approach is based on ethical views, regardless of market rates (Baum 2009). The prescriptive approach tends to build on an ethical view to not discriminate against future generations, which leads to a tendency for prescriptive-based rates to be lower than descriptive-based (market) rates (Swedish EPA 2006).

Given that the costs and benefits of an investment can be of varying types, literature has explored the use of (two) specific rates for (two) specific cost or benefit items, i.e. “multiple” or “dual” discount rates (Yang 2003; Weikard & Zhu 2005). In their case, they compare consumption goods with environmental goods, suggesting their value can be discounted using two different discount rates if future prices for environmental goods are unavailable or if consumption goods and environmental goods are non-substitutable – both of which may arguably be common cases. Grimes (2024) also advocates for multiple discount rates depending on the particular commodity (particular cost- or benefit item in a cost-benefit analysis), arguing the following:

> *“Typically, the same discount rate is used for a multitude of projects, differing perhaps only by a margin to allow for differing risk profiles. But this approach is entirely arbitrary. It assumes (even ignoring risk) that people are as relaxed about the state of the climate or a river in the future relative to today as they are about their market consumption or the state of a work of art in the future relative to today. There is no reason to make such an assumption. The use of dual (or, more generally, multiple) discount rates embodying differing rates of pure time preference for different goods can reflect differing societal weights placed on future streams of services from differing goods.” (p.14).*

The US government suggests using 7 percent as discount rate of investments and regulations to reflect the opportunity cost of capital (OMB 2023), with the motivation that this rate “approximates the marginal pretax rate of return on an average investment in the private sector in recent years”. When primarily private consumption is assessed, 3 percent is used instead, and an interval between 3-7 percent can be presented. This interval may give rise to significant variation in outcome with long-term benefits of green energy investments being three to six times higher when using the lower discount rate than when using the higher discount rate (Li & Pizer 2021).

4 Discount rates in NetZeroPlanner (NZP)

The NZP model aims to analyse the financial impacts of undertaking climate mitigation actions. The default discount rate in the current model is set to 3.5 %. The use of one single standard discount rate instead of multiple rates significantly simplifies and standardizes the model outputs, which facilitates scenario comparisons.

Notably, the model studies investments with a primary focus on a short-term time horizon (of one or a few decades), even though it also includes financial impacts beyond the target year, as investments may lead to long-term flows of costs or benefits. Nevertheless, most financial impacts are well within a 30-year timespan; hence there are not currently strong theoretical motivations for applying declining discount rates.

Finally, given the variety of different types of costs and benefits; representing both financial and non-market values, a balance between a descriptive and a prescriptive approach, such as the one presented by the UK Green Book (HM Treasury 2022) is applied. Altogether, these factors lead to a fixed discount rate of 3.5 % being applied in NZP, mirroring the UK Green Book discount rate.

5 References

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NetZeroPlanner Technical Annex 3: FAQ on Model-Specific Attributes

Items

1 What sectors are covered in NZP?

The following sectors are included in the NZP:

- Passenger transport
- Freight transport
- Buildings and heating
- Electricity
- Waste
- Other sectors (IPPU, AFOLU etc.)

While the first five sectors are covered in relatively high resolution, the other sectors are covered by a general lever that affects all other emissions. For cities with high emissions outside of the first five sectors, particular scrutiny should be given when evaluating the model output.

2 Why are some sectors covered more closely than others?

The sectors covered are the ones that are most relevant for European cities. The NZP is quite detailed in the sectors of mobility and heating, as that makes up a large proportion of scope 1 and 2 emissions for European cities. Other sectors that may be important for countries as a whole, like shipping and aviation, or agriculture or forestry, are less detailed. That means that actions such as rewetting wetlands, switch of industrial fuel to e.g. hydrogen, or use of bio-CCS are still areas that need future attention.

Both the mobility and the heating sectors are covered by a large number of available actions. A high resolution in terms of detailed, well-defined and narrowly delimited measures is available for electrification of buses, car-pooling and reduced transport needs. The same goes for freight transport with options to optimise logistics for example. For the buildings sector, actions are available covering renovations, energy efficiency measures, district heating fuels, local heating fuels.

3 How does NZP compare with other similar tools? Can NZP be integrated with other tools or platforms that cities might be using?

There are a number of similar tools and services available that overlap with the analyses of the NZP, such as Futureproofed, EU City Calc or Viable Cities Dashboard. The NZP has been optimised to be used in a broad European context for cities with high ambitions for climate neutrality by 2030. Specifically, it provides the output to fill in the key values of the Climate City Contracts of the cities. Apart from the sectoral coverage (see above), the NZP differs in various aspects.

The data underpinning the NZP is based on rigorous research with a high level of detail. While some data points underlying the model are based on European averages, many placeholders are also adapted to the cities' geography and energy mix. This is either done by using comparable cities data based on a number of Mission Cities' Climate City Contract submissions, or by publicly available data sources on country level such as Statista.

The structure of the calculations is also different around different tools. A more detailed explanation of how NZP converts inputs to outputs is available in Technical Annex 1. Differences could include specific assumptions, how co-impacts are calculated or whether data on greenhouse gas emissions is used for output calculations. Other models may be based on the assumption that the city knows its GHG emissions on a rather detailed level and ties the actions to those emission pools. The NZP calculates the emissions through the assumptions in the input sheet. For this reason, the impact of reduced pollutants (other than GHG emissions) is calculated by estimating how much the pollutants are reduced based on technical parameters like the emission intensities of the cars. Other models may use assumptions that proportionally tie pollutants' reduction to CO2 emissions (for which there may be reliable data) for example. For this reason, the same city using two different models may get widely different results, despite input assumptions being synchronised.

4 Can the NZP be used to evaluate individual projects?

The NZP is designed for cities to plan their overall investment needs and distribute them across stakeholders. This might give an overall insight of investment need for different actors, which can be compared with their financial ability to make these investments. It also helps clarify the benefits of the investments across stakeholders. This might be useful for the city as a whole to fund the transition, e.g. if green bonds are issued.

However, the model is not designed to evaluate individual investment projects such as investing in solar power. Some data points might be helpful in that effort, but it cannot replace specific bottom-up business case calculations. The NZP is a tool to comprehensively assess (or evaluate) the impact and track the progress of its climate action plan as a whole. In other words, it is a tool for top-down planning and governance of the climate neutrality journey. In addition to and in combination with a top-down governance tool such as the NZP, the city needs a bottom-up reporting process to monitor the impact of individual interventions of its climate action plan, so it can ensure that the overall plan is on track.

5 How does NZP handle discounting of future costs and benefits?

A default discount rate of 3.5 % is applied in Net Zero Planner. For motivations behind this choice, see NetZeroPlanner Technical Annex 4: Discounting in Net Zero Planner.

Costs and benefits that occur in the future have been discounted using an annual rate of 3.5%. This is because of the opportunity cost of money, where one could invest into another project with a certain return together with a general view that money today is worth more than money tomorrow. For a more detailed overview of why 3.5% was chosen, please refer to Technical Annex 2.

6 Is the social cost of carbon accounted for in the model?

No. The reason for not including the benefit of reducing carbon emissions specifically is that this reduction is the end-goal itself of the model. Benefits of carbon emissions reductions are global, whereas the typical reason for applying NetZeroPlanner is to study the local economic and financial case for net zero. Instead, co-benefits of emission reduction, such as health effects of reduced air pollution, when taking measures to reduce carbon emissions, are included.

The social cost of carbon is a monetised measure of the benefits from reduced GHG emissions and thus reduced climate impact. The social cost of carbon is excluded from the analysis as the whole purpose of the NZC project is to get to climate neutrality. Other co-benefits are important to quantify to strengthen the case for climate neutrality. These co-benefits generally also benefit the city itself, often even monetarily. The social cost of carbon generally covers economic benefits (from avoiding destructive climate change) that pertains to actors broader than the city itself.

There is an long-ranging academic debate on what the social cost of carbon actually is, where some argue for a low cost believe the impacts of climate change will not be so costly, and others believe it's much higher than e.g. current EU ETS prices, by being more pessimistic about the consequences of climate change or simply valuing future impacts higher[1]. This is also a reason not to include this number in the analysis.

7 Are only climate-related transition costs covered by the model?

Yes. The NZP is aimed at calculating additional investments needed to fulfil the climate transition. That means that only additional costs of the climate transition are considered, such as the additional cost of purchasing an electric bus compared to a fossil-fuelled bus. That excludes the total cost of the bus, which might be useful for a city to know when financing the transition, as the full cost may be needed to be funded to be able to make the switch. Other models may have other purposes than the NZP or have more flexibility in this regard. But the purpose of the NZP is to identify what additional resources need to be mobilised to ensure the climate transition.

8 How is Quality Assurance done for NZP?

Ahead of release of a new version of the NZP a rigorous amount of testing is carried out by various actors with insight into the economic model. This is done to both ensure accuracy of the numerical output and ease of use for cities. This is always done in various iterations to avoid to the best extent possible that new errors remain unresolved.

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[1] https://www.pnas.org/doi/10.1073/pnas.1315987111

9 What are considerations for Scope 3 emissions?

Scope 3 emissions are emissions produced by the city but processed outside the city border. Some of these emissions are captured by the NZP by including solid waste emissions that are incinerated outside the city boundaries. Emissions from the production of goods outside of the city purchased to be used in the city are not covered by the model as of now.

10 How can cities validate the model's outputs?

The NZP intends for an iterative process of working with the inputs and assumptions and for the cities to ponder about how realistic the outputs are. The process is thus just as or even more important than the final output. Identifying key assumptions and the impact of those in the output is the best way to get an understanding of the output.

11 What are the key data sources used in the model?

Please refer to Technical Annex 1 for a more detailed explanation of the data sources.

12 How can users provide feedback on the tool and its documentation?

There is a support function with an email to the developing team that could be used to provide feedback. Suggestions will be considered by the developing team for future versions of the model.