atelier
Positive Energy Districts

AmsTErdam BiLbao cItizen drivEn smaRt cities

Deliverable 2.6: City Vision 2050 for LHs and FCs

WP2, Task 2.4

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Document History

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DoA		The 8 participant cities will deliver a City Vision 2050, for guiding their urban energy transition challenges and integrate it into their planning procedures for effective implementation.

Date	Version	Author	Comment
26/01/2023	1	TEC	Table of Content
30/11/2023	2	Cities	Atelier cities contributions
08/12/2023	3	TEC	Deliverable for revision by project partners
22/12/2023	4	CAR, TNO	Comments to the deliverable
29/12/2023	5	TEC	Consolidated version for project coordinator
29/12//2023	6	AMS	Final review of deliverable

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Table of Content

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 864374.

Table of Tables

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 864374.

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Table of Figures

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Abbreviations and Acronyms

Acronym	Description
BaU	Business as Usual
BM	Business Model
CCC	Climate City Contract
CHP	Combined Heat and Power
CoM	Covenant of Mayors
DoA	Description of Action
DH	District Heating
DHW	Domestic Hot Water
EC	European Commission
EE	Energy Efficiency
ETS	Emission Trade System
EU	European Union
FW	Fellow
FWC	Fellow City
GDP	Gross Domestic Product
GHG	Greenhouse gas
GIS	Geographic Information Systems
ICT	Information and Communication Technologies
IPCC	Intergovernmental Panel on Climate Change
KPI	Key Performance Indicator
LH	Lighthouse
LHC	Lighthouse City
LULUCF	Land use, Land-use change, and forestry
NGO	Non-Governmental Organisation
NZEB	Nearly Zero-Energy Building
PED	Positive Energy District
PPP	Public Private Partnership
PV	Photovoltaic
RES	Renewable Energy Sources

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SCC	Smart Cities and Communities
SCPG	Smart City Planning Group
SEAP	Sustainable Energy Action Plan
SECAP	Sustainable Energy and Climate Action Plan
SME	Small and Medium Enterprise
SUMP	Sustainable Urban Mobility Plan
SWOT	Strengths, Weaknesses, Opportunities and Threats (analysis)
UNFCCC	United Nations Framework Convention on Climate Change
WP	Work Package

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0. Executive Summary

The present deliverable includes the bold city vision of the 8 ATELIER cities. This work is part of the WP2 “City Vision” of ATELIER project and provides the city vision and strategy framework needed in the planning process.

WP2 aims at the development of a City Vision for every city in the project. The objective of the whole WP is structure under the Cities4ZERO methodology (Urrutia et al, 2020[1]) to guide the cities to develop the urban transformation strategy for decarbonisation. D2.6 is one of the most relevant documents of WP2 because it presents the results of the cities after more than 3 years working on implementing and developing the methodologies, tools and supporting material provided to define a consolidated city vision.

Beyond the city vision, Bratislava, Budapest, Krakow, Matosinhos and Riga present in this deliverable their alternative and master scenarios to drive the city vision as well. In the case of Bratislava, an update of its energy diagnosis and business as usual scenario is given.

For the particular case of Bilbao, Copenhagen and Amsterdam, that have already developed their city vision or that followed another approach, a lessons’ learnt section is included to provide valuable information to other cities in the work of defining their city vision, in monitoring the results of the climate neutral plans implementation and in thinking what comes after reaching carbon neutrality.

This deliverable is a proof of the remarkable effort that ATELIER cities are doing to decarbonize their energy systems. They have created mechanism to involve all the relevant stakeholders that have to be part of the process, they have collected and analyse their energy system related information, they have reflected about the most suitable pathways to become carbon neutral and, after numerous discussions, they have established their city vision and a viable master scenario that will allow to accomplish it.

City vision and master scenarios presented in this deliverable will serve to create/update the cities action plans in next steps of WP2. Some of the cities will use this information for the SECAPs updating, while others cities that are part of the EU Mission: Climate-Neutral and Smart Cities, aimed at delivering 100 climate-neutral and smart cities by 2030, will take the opportunity to develop their Climate City Contracts.

This work has been developed by Tecnalia together with ATELIER cities. TNO supported Amsterdam in the process of reporting.

[1] https://doi.org/10.3390/su12093590

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1. Introduction

WP2 intends to develop a 2050 City Vision for the cities of the project. With that purpose, the flow of the work package is structured according to *Cities4ZERO: The Urban Transformation Strategy for Cities' Decarbonisation* (Urrutia et al, 2020[2]), a step-by-step methodology that guides the cities through the process of developing the most appropriate strategies, plans and projects as well as looking for commitment of key local stakeholders for an effective transition; all from an integrated planning approach.

Within Cities4ZERO methodology, WP2 is focused on the Strategic Stage (Figure 1), providing a strategic planning framework which enables the cities to:

- Engage key city stakeholders (institutional analysis and Smart City Planning Groups).
- Review the planning framework of the city.
- Analyse and diagnose the city' strengths and opportunities.
- Formulate the co-visioning process for urban transformation towards energy transition, including potential future scenarios.
- Develop the strategic plans (SECAP in ATELIER case) to deploy that city vision, identifying the key projects for the city.

In the case of D2.6 – *City Vision 2050 for LHs and FCs*, the work developed in this deliverable corresponds to Step 4 ENGAGE of Cities4ZERO methodology, where City Vision of the 8 ATELIER cities is provided.

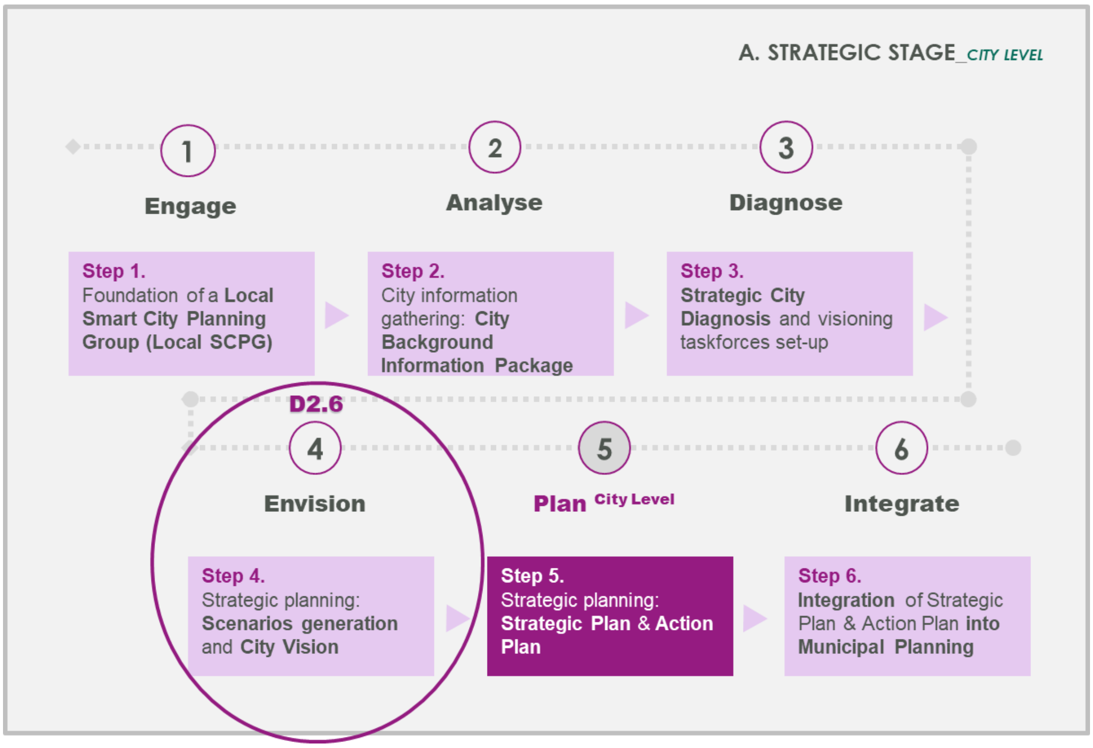

Figure 1. Strategic Stage in Cities4ZERO approach by Tecnalia (Urrutia et al, 2020)

[2] https://doi.org/10.3390/su12093590

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1.1. Purpose and Target Group

The main purpose of this deliverable *"D2.6 City Vision 2050 for LHs and FCs"* is reporting the city vision of ATELIER cities. All the activities carried out previously within WP2, intended to facilitate the development of the city vision, are presented in this deliverable. Therefore, D2.6 is one of the most relevant documents of WP2 because it presents the results of the cities after more than 3 years working on implementing and developing the methodologies, tools and supporting material provided to define a consolidated city vision. In brief, the material that guided the city vision included in this deliverable was proposed and presented in previous WP2 deliverables as follows:

- August 2020 - D2.1 Planning framework: report on each city, encompassing a deep analysis of the plans that affect the city.
- January 2021 - D2.2 Report on Smart City Planning Groups (SCPG): cities defined the governance model that will drive the city vision creation.
- February 2021- D2.3 Common methodological framework for vision development: the Cities4ZERO methodology for city vision creation is described.
- June 2021 - D2.4 Vision co-development roadmap for each city: the process to develop the city vision in each ATELIER city was provided, according to the methodology defined in D2.3 and adapted to each city context.
- December 2021 - D2.5 Prioritization matrix – tool for each city: the energy diagnosis and the business as usual scenario of the cities was provided. Moreover, Bilbao´s city vision was provided as front runner in Cities4ZERO methodology implementation. How to prioritize among energy transition narratives to define the master scenario was explained as well.

Therefore, this document presents the city vision obtained from the application of the improved version of Cities4ZERO methodology presented in D2.3 and completed in D2.5 (see section 3 Overall Approach).The city vision creation was driven by the local governance model created and presented in D2.2 following the roadmap described in D2.4 and supported in the analysis of plans included in D2.1 and the energy system analysis presented in D.2.5.

D2.6, as well as D2.3[3] where the methodology was presented, are public and thus, available at project website. The intention is to help other cities in the process of defining their carbon neutral transition by providing the methodology and the example of how 8 European cities have implemented the method according to their specific characteristics and challenges.

It has to be noted that Bilbao presented its city vision in D2.5. In the case of Amsterdam a different approach for city vision development was followed (see D2.3) and, before ATELIER project started, Copenhagen had already developed its city vision and currently is working on the post-neutrality plan (see section 5.3 The case of Copenhagen: working in post-neutrality plan). Respectively, these particularities enriched the work of the ATELIER fellow cities by serving as an example, by providing knowledge beyond Cities4ZERO methodology and by explaining what the cities will find after achieving carbon neutral objectives.

Focusing on D2.6, the present deliverable is structured as follows:

The present section 1 gives an introduction to the entire WP2, to the methodology carried out in it, as well as to the deliverable and its distribution (by chapters and by partners).

[3] https://smartcity-atelier.eu/outcomes/deliverables/d2-3/

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The section 2 of this document addresses its objectives, as well as its expected impact.

The section 3 summarizes the overall approach. Considering that there is an entire deliverable (D2.3) focused in explaining the methodology followed, section 3 provides just an overview of it.

Section 4, named ATELIER cities' vision 2050, presents the main outcome of the deliverable by depicting the city vision of the 8 ATELIER cities. The section includes information about the process that the cities followed for city vision development, the alternative and/or master scenarios of 4 out of the 8 ATELIER cities and information about the role that the Positive Energy Districts (PEDs) play in the city vision.

The section 5 includes information regarding the Lessons learnt in City Vision creation process.

Finally, the deliverable presents the Conclusions in section 6.

1.2. Contributions of Partners

The following Table 1 depicts the main contributions from project partners in the development of this deliverable.

Table 1. Contributions of Partners

Partner short name	Contributions
CARTIF	Deliverable revision
TNO	Sections 4.1 and 5.1, deliverable revision
AMST	Contributions to Sections 4.1 and 5.1
City of Bilbao	Sections 4.2.2 and 5.2
MunBud	Sections 4.4.1, 4.4.2 and 4.4.4
COP	Sections 4.5 and 5.3
RIGA EnAg	Sections 4.8.1, 4.8.2 and 4.8.4.
BRATISLAVA City	Sections 4.3.1, 4.3.2 and 4.3.4.
City of Krakow	Sections 4.6.1, 4.6.2 and 4.6.4.
Matosinhos	Sections 4.7.1, 4.7.2 and 4.7.4.
Tecnalia	Deliverable and Work Package leader. Developer of all remaining sections.

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2. Objectives and Expected Impact

2.1. Objectives

The main objective of this report is to present the city vision of the 8 ATELIER cities: Amsterdam, Bilbao, Bratislava, Budapest, Copenhagen, Krakow, Matosinhos and Riga. This report answers ATELIER project Milestone MS8, related to the “City Vision 2050 for LH and Fellow Cities”. The city vision reported in this deliverable will guide their urban transition challenges and set the basis to update and/or develop their action plans.

This deliverable, as well as the whole WP2, is based on the Cities4ZERO methodology. Cities4ZERO aims to be a collaborative process, in which the main stakeholders are called to participate in the whole City Vision generation process. This relates to the framework of the Smart City Planning Groups procedures, which is elaborately described in D2.2[4]. The Cities4ZERO guides cities on how to overcome their urban energy transition challenges and achieve their objectives, showing them a common path for effective implementation, considering integral urban planning principles as a key aspect to be included in their existing planning procedures.

Taking this general methodology as a starting point, cities co-designed their own working method, adapting it to their context and their technical, political and governance reality. In this context, D2.6 explains how each city has implemented the process, the alternative scenarios and master scenarios obtained according to the decisions taken during the participatory processes and the City Vision that will drive the carbon neutral conversion of the city.

2.2. Expected impact

The 8 ATELIER cities present their city vision in this deliverable. In this sense, Bratislava, Budapest, Krakow, Matosinhos and Riga present their alternative and master scenarios to drive the city vision as well. In the case of Bratislava, an update of its energy diagnosis and business as usual scenario is given.

For the particular case of Bilbao, Copenhagen and Amsterdam, that have already developed their city vision or that followed another approach, a lessons’ learnt section is included in this deliverable to provide valuable information to other cities in the work of defining their city vision, in monitoring the results of the climate neutral plans implementation and in thinking what comes after reaching carbon neutrality.

City vision and master scenarios presented in this deliverable will serve to create/update the cities action plans in next steps of WP2. Some of the cities will use this information for the SECAPs updating, while others cities that are part of the EU Mission: Climate-Neutral and Smart Cities, aimed at delivering 100 climate-neutral and smart cities by 2030, will take the opportunity to develop their Climate City Contracts.

Beyond Atelier activities, WP2 is catching attention by other cities, who asked WP2 participants to present in a Workshop the methodology being followed and the cities experience in implementing it. The workshop was done online in May 2023 with the title “Bold city vision”.

[4] *D2.2_Report on Smart City Planning Groups (SCPGs)* which explains the SCPGs general characteristics and potentialities to establish a suitable governance model for City Vision creation.

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Considering that this is a public report, it is expected that cities interested in creating their vision find relevance in the content presented.

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3. Overall Approach: Cities4ZERO methodology for city vision development in a nutshell

This section summarizes the overall approach proposed for city vision development, based on the Cities4ZERO methodology presented in D2.3 Common methodological framework for vision development and completed in D2.5 Prioritization matrix – tool for each city. According to the application of explained method, the city vision of 5 out of 8 ATELIER cities is presented in section 4 ATELIER cities' vision 2050 (Bratislava, Budapest, Krakow, Matosinhos and Riga). Bilbao presented its city vision in D2.5, serving as example for other ATELIER cities of the Cities4ZERO methodology implementation. Amsterdam and Copenhagen´s city vision is presented in section 4 as well, following an approach which is different to Bilbao. This, to demonstrate alternative ways of working, as a one-size-fits all approach is not likely. Therefore, the purpose of this section is providing an overview of the applied methodology to facilitate the understanding on how the results presented in section 4 ATELIER cities' vision 2050 were obtained. Information that follows has been already reported in previous deliverables of WP2. Here an updated version is given.

Common foresight methodological framework that has been applied was presented in D2.3[5]. ATELIER methodological framework for a co-diagnosis, a co-scenario development and a co-vision 2050 generation, is supported by the Cities4ZERO methodology (Urrutia et al, 2020[6]). Moreover, D2.4[7] adapts the general methodological framework of D2.3 to local city conditions, facilitating proper implementation according to the local context; resulting in the ability for co-diagnosis, co-generation of future scenarios and the final co-creation of their City Vision 2050. This adaptation was done through the development of own roadmaps towards a 2050 City Vision Development.

Figure 2 presents the General Roadmap created for cities´ vision 2050 development. It includes the 6 steps of the Cities4ZERO methodology in the right part (Engage, Analyse, Diagnosis, Envision, Plan and Integrate), the timeline and the main actions that are suggested to the cities to properly achieve a co-creative vision 2050 development. The figure shows the interrelation between the steps and how the actions enriched each other.

[5] *D2.3_Common methodological framework for Vision development*
[6] https://doi.org/10.3390/su12093590
[7] *D2.4_Vision co-development roadmap for each city*

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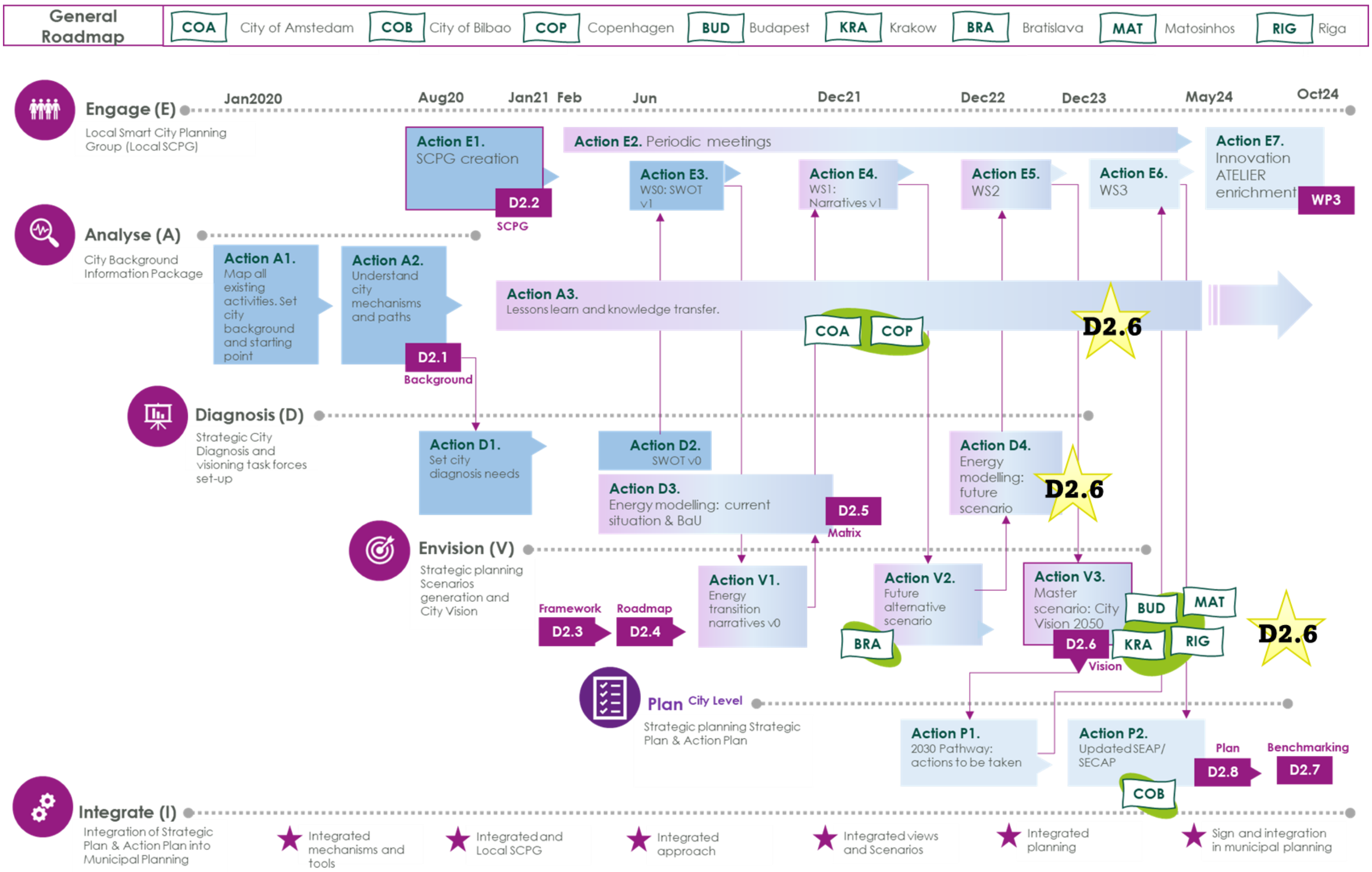

Figure 2. General Roadmap for vision 2050 co-development (Source: Updated from D2.4)

Figure 2 reflects in lilac the actions that were active since the presentation of the last deliverable of WP2. Moreover, highlighted with a star, several of the main results that can be found in this report are marked:

- The energy modelling of future alternative scenarios: see section 4
- The city vision and the master scenario: see section 4
- Lessons learnt and knowledge transfer: see section 5

Explaining in few words how the cities have been working in creating their city vision, it has to be mentioned that firstly, they worked in defining the energy transition narratives of their future alternative scenarios. Cities were invited to define these scenarios in collaboration with members of the SCPGs. Workshops were held to facilitate discussion and supporting information like the swot analysis, the energy diagnosis and the business as usual scenario created in previous steps of the WP were utilized to make more informative decisions. Lastly, after several rounds of discussion among relevant stakeholders, cities Master scenarios to drive the city visions were defined. According to the Cities4ZERO methodology, Master scenarios describe the agreed City Vision and are the basis for the development of the city's strategic planning process, where the City Vision is transformed into goals and specific actions.

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Cities Master scenarios have been modelled within the LEAP city energy models developed and outlined in deliverable D2.5. Indeed, Master scenarios are based on the diagnosis and BaU scenario described in the aforementioned deliverable and take into account cities starting points and baseline trends while modelling specific measures, actions and policies aimed at achieving the City Vision. It should be noted that, as new data has been available, some city energy models have been updated. Moreover, either because of data availability, objectives, scopes, or cities interests, sectors (and their breakdowns) represented in the different models may slightly differ from city to city, although the main city end-use sectors (i.e., residential buildings, private tertiary buildings, municipal buildings, municipal fleet, public transport fleet, or private transport) are common for all cities.

Finally, to define its City Vision, each city has adapted the Cities4ZERO based on their specific needs. In the sections named "process followed to define the city vision" of section 4, each city explains how they have implemented the Cities4ZERO method.

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4. ATELIER cities' vision 2050

4.1. Amsterdam

The Climate Neutral Roadmap 2050 is enacted in 2020. With this roadmap the city of Amsterdam is mainly focusing on the last step in the Cities4ZERO methodology with various ongoing efforts to integrate the vision into the city's daily operations. In section 4.1.1 the development process of the Climate Neutral Roadmap 2050 is described, based on D2.1 and **a series of interviews that was conducted between July and October 2020. This is followed by** a the section 4.1.2 which outlines the key elements of the Climate Neutral Roadmap 2050. Later, in section 5.1 we will reflect on the first three years of the Climate Neutral Roadmap being in place and identify lessons learned.

4.1.1. Process followed for city vision development

The development process of the Climate Neutral Roadmap 2050 started in the Summer of 2018, after the new city council established the coalition agreement for the administrative period of 2018-2022. In this coalition agreement called 'a new spring and a new sound', Amsterdam sets the ambition to become a frontrunner city in the energy and materials transition. With several priorities such as: the reuse of raw materials, natural gas-free neighbourhoods, generating sustainable energy, structurally rethinking the use of energy and emission-free traffic. With this coalition agreement, the cornerstones of the Climate Neutral 2050 ambition were set.

During that period, the climate neutral team, which is part of the spatial planning & sustainability department of the Municipality of Amsterdam, started with a core team of six people. The Climate Neutral Roadmap did not have a well-defined project plan at first. The approach followed is the result of immense effort of the team to create an overview of internal dependencies between projects, programs, departments and responsibilities in order to get a holistic view of the challenge at hand. Ultimately, the process can be described along four main elements, namely:

1. *Research themes.* Which was focused on determining the thematic structure of the transition paths, identifying what was already in place and how to connect current and future efforts.
2. *Management conversations*. Referring to internal stakeholder management and decisions regarding roles, responsibilities and creating internal support for the Climate Neutral Roadmap 2050.
3. *Data collection*. Which was at the basis for the climate budget, calculating the relevant indicators of the portfolio of actions and the according CO_2 reductions.
4. *City conversations.* In which the participation with a wide variety of over 300 city stakeholders was set-up and coordinated.

Figure 3 depicts these sub-processes as part of the development of the Climate Neutral Roadmap 2050. Deliverable 2.1 described these sub-processes in more detail. In the first months of the process, the core team worked on the first version of the Roadmap which was adopted in the beginning of 2019. This first version was called *'invitation to the city'* which outlined the vision and key ambitions and opened up the participation process with key stakeholders in the city.

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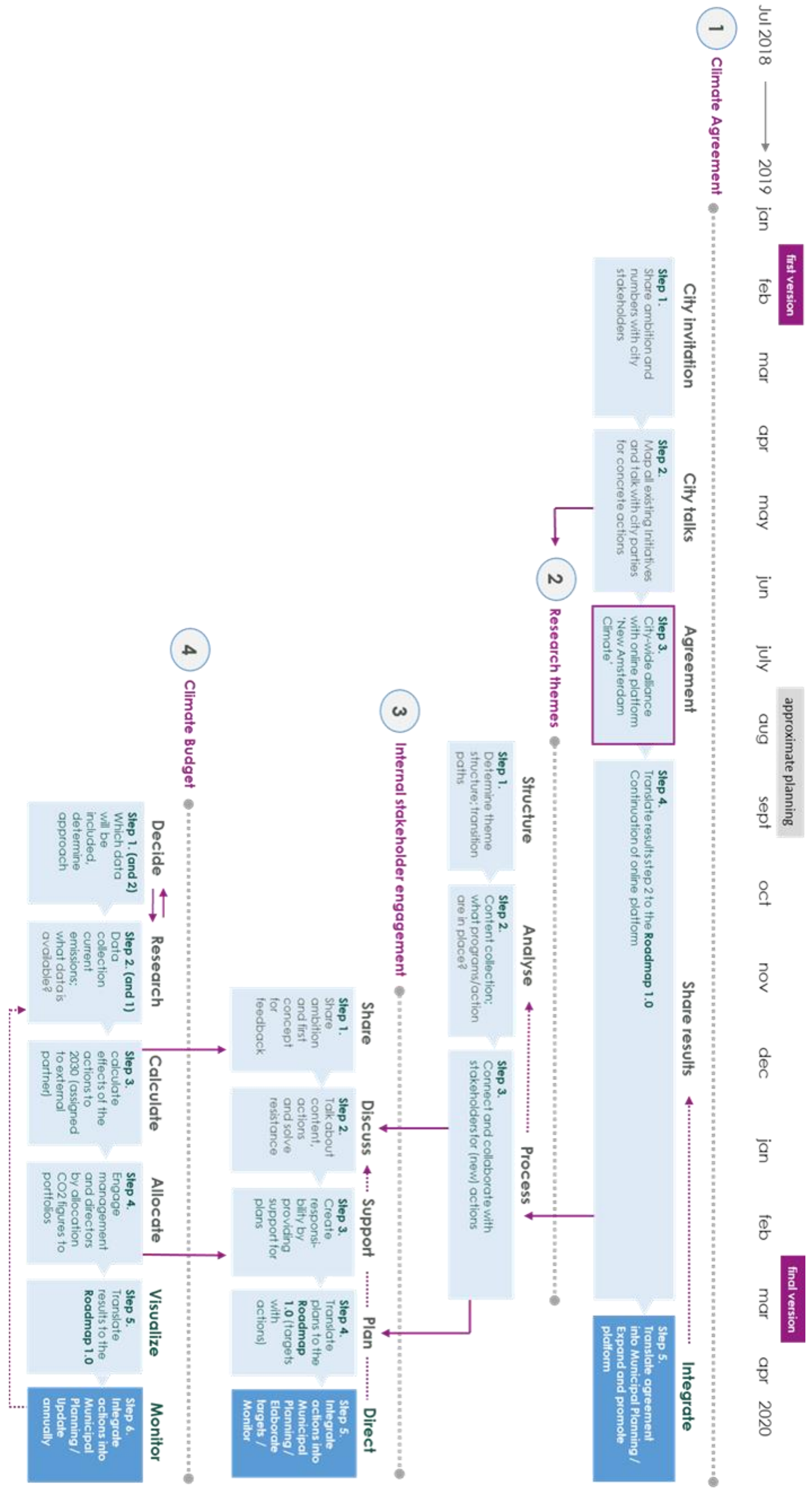

Figure 3. Amsterdam Climate Neutral Roadmap 2050 development process summarized.

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With the *'invitation to the city'* the core team started a comprehensive process of exploration and discussions with residents, companies and other organisations on how to achieve the city's ambition towards climate neutrality. This document described the goals that the city had set and was meant to be used as a conversation starter in order to flesh out the concrete actions and measures that stakeholders could take to achieve these goals. The team worked on this process intensively for over a year, resulting in the Amsterdam Climate Agreement. And a new online platform (www.nieuwamsterdamsklimaat.nl), that hosts more than 200 initiatives that could contribute to a sustainable city. Based on the input from this participative process, the first version of the Roadmap was updated and improved, leading to the adoption of the Amsterdam Climate Neutral Roadmap 2050 in the Spring of 2020.

The Amsterdam Climate Neutral Roadmap is not only a document in which the Municipality of Amsterdam presents her ambition and vision on the energy transition from 2020 towards 2050, but it also describes the necessary actions on the short term to achieve that ambition. The main goal is to cut CO_2 emission by 95% compared to 1990 levels in 2050, by reducing energy consumption as much as possible, generating renewable energy and working towards a circular economy. In the Roadmap the municipality discusses the key elements that play a role in the transition away from fossil fuels and towards sustainable alternatives. In the next section these goals will be elaborated in more detail.

In order to monitor and evaluate the progress of the Climate Neutral Roadmap, the municipality introduced the 'climate budget' and an annual Climate Report. The climate budget provides insight into who is responsible for what CO_2 emissions and the effect of the proposed actions and measures on the emission reduction. As of 2020, the municipality is monitoring and reporting these numbers annually in the climate report, describing the progress that is made on several indicators, such as reduced carbon emissions. When the figures are not aligned with the goals, the idea is that the approach can be adapted timely and additional measures can be introduced.

4.1.2. Amsterdam Climate Neutral 2050 Roadmap: a City vision

Introducing the Climate Neutral Roadmap with: *'we want Amsterdam to be a green, healthy, prosperous and future-proof city, where everyone can benefit maximally from the opportunities brought by this social transformation'*, the municipality of Amsterdam sets her ambitions high. As said before, the main goal of the Amsterdam Climate Neutral Roadmap 2050 is to phase out fossil fuels rapidly and cut CO_2 emissions by 95% compared to 1990 levels in 2050, with an intermediate goal of 55% reduced CO_2 emissions in 2030. Additionally, the Roadmap includes several measures and actions that need to be taken in order to become a climate neutral city. Moreover, the municipality of Amsterdam states that the realization of this ambition is only possible in collaboration with residents, businesses and other organizations.

The Roadmap is divided along four transition paths: *built environment*, *mobility*, *electricity* and *harbour & industry*. **Figure 4** presents the current greenhouse gas emissions per transition path in order the get grip on the existing challenge. The Roadmap document describes the key components of the strategy to set and keep the transition towards a climate neutral city in motion, accompanied by measures and the expected effects of measures for each transition path. The Amsterdam Climate Neutral Roadmap 2050 is the start of an adaptive process, consisting of intensive cooperation, experimentation and learning to be able to make adjustments when necessary.

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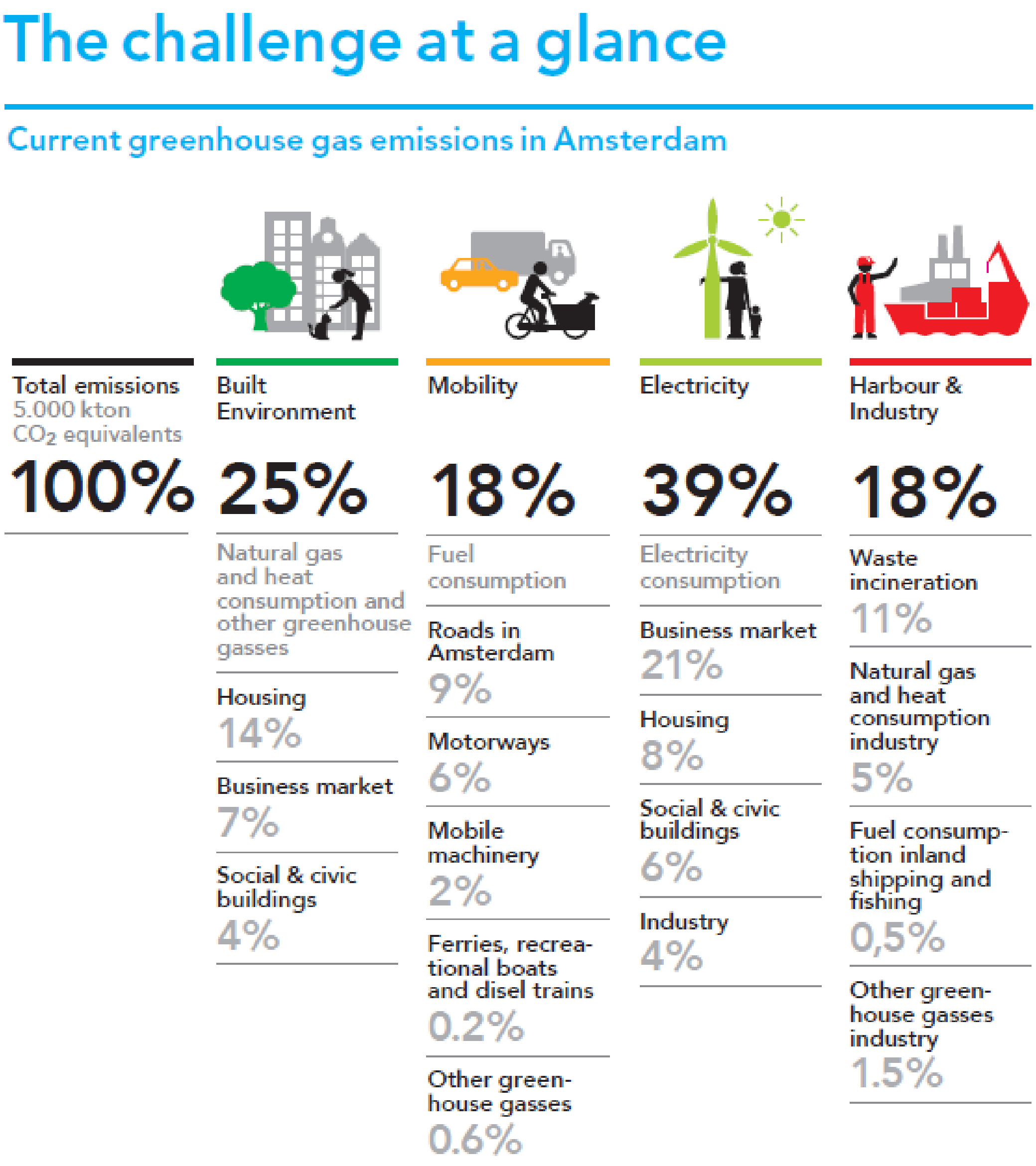

Figure 4: The challenge at a glance (*retrieved from: Amsterdam Climate Neutral Roadmap 2050*).

Figure 4 shows that for the 5000 kton emissions in 2017, 25% of the emissions came from the built environment and its natural gas and heat consumption, 18% from fuel consumption for mobility, 39% from electricity consumption and the last 18% from the harbour and industry. In 1990 Amsterdam was emitting 3810 kton of greenhouse gases (see Figure 5) This figure increased to 5510 kton in 2010, but decreased to 5000 kton in 2017. The city's ambition is to reduce its greenhouse gas emissions by 95% compared to 1990 levels in 2050 and by 55% in 2030. Taking into account all planned actions and measures from the central government, the Municipality of Amsterdam, citizens, companies and other organisations, Figure 5 shows that the expected reduction by 2030 is estimated to be 48% compared to 1990. The projection in Figure 5 provides an overview of the challenge that the city of Amsterdam is facing, where the current emissions are coming from and points out that additional measures are necessary in order to be able to achieve the intended results.

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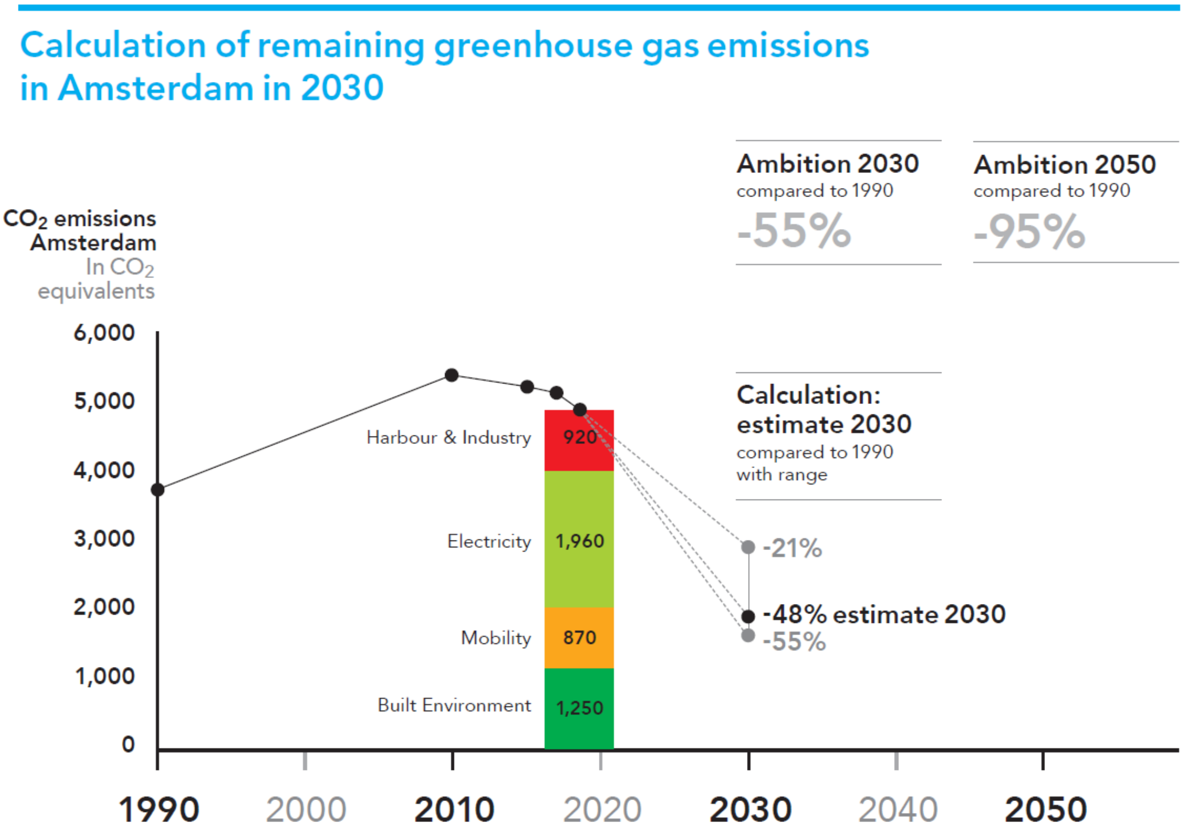

Figure 5: Calculation of remaining greenhouse gas emissions in Amsterdam in 2030 (*retrieved from: Amsterdam Climate Neutral Roadmap 2050*).

The Amsterdam Climate Neutral Roadmap 2050 describes 16 pillars within the four transition paths of respectively the Built Environment, Mobility, Electricity and Harbour & Industry, and shows what actions will be taken to achieve greenhouse gas emission reductions. We continue this section with the primary goals and measures and the pillars that inhabit the four transition paths.

Built environment

In base-year 2017, 25% (1250 kton) of the CO_2 emissions of the city comes from the built environment. This 1250 kton of emissions can be divided into 658 kton from natural gas consumption by houses, 263 kton from natural gas consumption by the business market, 222 kton from natural gas consumption by social and civic buildings, 68 kton from heat consumption by houses and other buildings and the final 49 kton are other greenhouse gases. Therefore, the main goals in this transition path are that: the entire city should be natural gas-free by 2040, all buildings in the city must be heated in a sustainable way by 2050, and the municipal organization must be climate-neutral in 2030. These goals are related to three key-area's in this transition path, namely: a natural gas-free built environment, energy-efficient buildings and climate neutral growth of the city. The focus is not only on phasing out natural gas and introducing alternative heat sources, but also on energy efficiency. The existing buildings pose the greatest challenge. The actions that support key area's in this first transition path are:

- Scaling up the natural gas phase-out, district by district.

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- Developing diverse and sustainable sources for the heat distribution grid.
- Building a citywide heat infrastructure.
- Increasing the energy efficiency of residential dwellings. Provide advice to each and every home owner.
- Increasing the energy efficiency of the business market:
  - Making business processes more energy efficient.
  - Enforcement from the Environmental Code and the Energy Efficiency Directive (EED) is intensified.
  - As of 2023 energy label C becomes mandatory for offices.
- Increasing the energy efficiency of around 3000 social and civic building via a support program that consists of: energy scans, subsidies and loans with a low interest rate.
- Energy neutral construction:
  - The city will only build energy-neutral and energy-producing.
  - The use of emission-free construction equipment and logistics.
  - Working towards ambitious standards for energy performance of new construction.

Mobility

The second transition path is primarily focussing on the carbon emissions from the transport of passengers and goods. The growing city, both in size as well as people, leads to an increased amount of travelled kilometres. In 2017, 18% (870 kton) of the CO_2 emissions of Amsterdam came from the mobility sector and its fuel consumption. This 870 kton can be split up in 431 kton from Amsterdam's roads, 307 kton from the motorways, 98 kton from mobile machinery, 8 kton from ferries, recreational boats and diesel trains and 31 kton are other greenhouse gases. The main goal in this transition pathway is to minimise the amount of polluting kilometres by making the switch towards more sustainable forms of transportation. An intermediate goal to stimulate this development is that all traffic in the built environment must be emission-free by 2030. The second transition path, includes the following supporting actions:

- Limiting polluting traffic via:
  - Stimulating the transition to sustainable means of transport.
  - Facilitating sufficient sustainability alternatives.
  - Regulation to reduce parking spaces and close streets for motorized traffic.
- Cleaning up all polluting vehicles and vessels by:
  - Encourage emission-free transport through subsidies and privileges for clean vehicles.
  - Facilitating emission-free transport through special parking spaces and charging infrastructure.
  - Regulate fossil-powered vehicles by establishing environmental zones.

Electricity

The main focus of the third transition path is the generation of sustainable electricity in order to meet the electricity demand which is expected to grow as a result from increasing digitalisation, the need for electricity to heat buildings instead of natural gas and to drive electric vehicles. In 2017, 39% (1960 kton) of the CO_2 emission of Amsterdam came from electricity

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consumption. In more detail, 397 kton came from the electricity consumption of houses, 1064 kton from the business market, 283 kton from social and civic buildings and 221 kton from industry. Moreover, only 6% of the electricity used in Amsterdam in 2017 was sustainably produced. The main goal of this transition path therefore is to maximise the generation of sustainable electricity. The presence of electricity infrastructure with sufficient capacity is a precondition to achieve this and realize the ambition to become a climate neutral city. This transition path covers the following actions:

- Maximizing solar energy generation on roofs, such that in 2050 all possible roofs are utilized for solar PV, by:
  - Inspiring citizens, take away obstacles, foster collaboration to maximize the opportunities for solar PV.
  - Research the possibility for the municipality to steer solar PV on large roofs.
- Optimizing use of wind energy via:
  - Identification of search area's for wind energy and within these search areas reserve space for the installation of wind turbines.
  - In collaboration with spatial experts, citizens, and other stakeholders the decision-making process is shaped and prepared for the installation of new wind turbines.
- Developing a future-proof electricity infrastructure.

Harbour & Industry

The fourth transition path focuses on the challenge and opportunity that Amsterdam's harbour faces in going from a fossil energy cluster and becoming a frontrunner in sustainable energy. Besides the logistical function and its position in the global energy trade, the harbour also houses industrial activity which consumes and generates energy. In 2017, 18% (920 kton) of Amsterdam's CO_2 emissions came from the Harbour & Industry. More specifically, 553 kton came from waste incineration, 262 kton from natural gas and heat consumption by the industry, 24 kton from fuel consumption of inland shipping and fishing and 76 kton were other greenhouse gasses from the industry. The harbour area as a *'sustainable battery for the city, region and Europe'* is a vision of the future harbour with few or zero carbon emissions and lots of space for generating, storing and distributing renewable energy to end-users on an industrial scale. Therefore, efforts are being made to: save energy in the industry, develop a green hydrogen economy and phase out the use of fossil fuels completely. The actions that support this ambition are:

- Transforming the harbour into a sustainable battery. The port economy in Amsterdam is changing from storage and transhipment of fossil cargo flows, such as coal and oil products, to one of the most sustainable ports in Europe based fully on sustainable energy and a fuel cluster with green hydrogen, biofuels and synthetic fuels. We are committed to phasing out coal by 2030 and all other fossil fuels by 2050.
- Developing the green hydrogen economy.
  - It is important that relevant authorities and governments intervene in a timely manner on current hydrogen developments and obtain the leading position that the region aspires to.
  - It is important that cooperation in the region is further expanded to take concrete steps in developing the regional hydrogen economy, including in the areas of infrastructure, hydrogen production, legislation and regulations and financing.

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- Carbon capture, storage and utilization.
    - The municipality supports CO_2 capture in production processes for which there are currently no alternative fossil-free production methods.
    - In the future, captured CO_2 can be used in the production of, for example, synthetic kerosene, which is essential for making aviation more sustainable.
- Energy efficiency in industry.

Monitoring: the annual Climate Report
To monitor the progress of the Amsterdam Climate Neutral 2050 Roadmap, a plethora of indicators are introduced besides CO_2 emissions. Table 2 below shows an overview of the indicators and target values per transition path.

Table 2: Indicators and target values per transition path (retrieved from: Amsterdam Climate Neutral Roadmap 2050).

Indicator by transition path/subject	Starting point (and year)	Target values (and year)
Built environment		
Total number of home equivalents natural gas-free (of existing buildings in Amsterdam in 2019)	91.000 (2019)	260.000 (2030)
Number of home equivalents for which the feasibility phase of the district-based gas phase out program started in the given year	3000 (2019)	5.000 (2020) 10.000 (2021) 15.000 (2022) 22.000 (2023) 29.000 (2024)
Number of home equivalents for which an investment decision has been taken to phase out natural gasin the given year	1700 (2019)	3.000 (2020) 5.000 (2021) 10.000 (2022) 15.000 (2023) 22.000 (2024)
Annual reduction in carbon emissions from housing corporation homes	1,5% (2019)	At least 3% (2023)
Number of extra owner-occupier associations (VvEs) supported per year	N/A	300 VvEs, 11.000 homes (2020) 400 VvEs, 38.000 homes (2021)
Number of supporting companies	Unknown	increasing trend
Number of companies monitored by the Regional Agency for the Environment	976 planned (2017)	1.550 checks per year, focusing on energy theme
Number of social and civic buildings where energy measures are taken	-	Increasing trend
% of permits issued for new buildings at least Energy-Neutral Building (ENG) level	-	Increasing trend
% of new-build tenders with minimum level ENG	-	Increasing trend
Mobility		
% of kilometres of motorized transport on Amsterdam's roads driven by electric vehicles	3,1% (2019)	95% (2030)
Number of public electric (rapid-)charging points in Amsterdam	3.300 (2019)	Not a target value, because municipality facilitates demand. Only follow development.
Electricity		
Total installed capacity (in MW) of solar energy in Amsterdam	73 (end of 2019)	100 (2020) 150 (2021) 250 (2022) 350 (2023) 550 (2030)
Total installed capacity (in MW) of wind energy in Amsterdam	66 (mid-2019)	77 (2021) 127 (2030)

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Total number of land allocations (tenders and one-on-one permits) for wind turbines in Amsterdam	N/A	4 (2020) 6 (2021) 8 (2022) 10 (2023)
Harbour & Industry		
Non-fossil revenue	Unknown	65% (2025)
Storage capacity used for alternative fuels	Unknown	12,5% (2025)
Space for circular activities	Unknown	25 hectares (2025)
Reduced CO_2 emissions	920 kton (2017)	10% (2025) 55% (2030) 100% (2050)

4.1.3. The role of PED in City Vision

While being a frontrunner in the Dutch energy transition, the city of Amsterdam faces several challenges which may hamper the progress in the energy transition in the coming years. These challenges are related to the scarcity in space and in capacity on the electricity grid. According to an energy system study by DSO Liander in 2021, around 80% of the sub-stations in Amsterdam will be congested in 2030, while in 2050 the load on the grid will be a factor 3 to 4.5 higher. This, while demand is expected to keep on growing, and grid congestion is mainly caused by increases in demand. The study by Liander illustrated that data centers (19%), new construction (16%) and mobility (12%) will have the biggest impact. It is in this challenge that positive energy districts are a crucial necessity in the energy transition.

In Amsterdam's Climate Neutral Roadmap 2050 PEDs are not explicitly mentioned. However, the three main functional elements of PEDs – Energy Efficiency, Energy Flexibility and Energy Production - are repeatedly mentioned as important elements of the roadmap. As such, it stated that *the city is moving from a relatively flat one-dimensional energy network to integrated smart networks that serve energy use for living, working, industry and mobility.* This increased complexity of the grid requires the implementation of increased smartness. Moreover, solar PV is inextricably linked to a future sustainable energy system, and the city is looking into the targeted charging of electric cars with solar energy, or to store this energy in a battery and use it when there is a high demand for energy. To this end, the city works with DSO Liander on smart grid management with sustainable energy.

The Smart Energy System in Schoonschip – the most sustainable floating houses, enabled to locally share energy - is included as a demonstration project in the Climate Neutral Roadmap. This project is part of the Buiksloterham district which is envisioned to be the first PED in the city. The city strategy encompasses the scaling-up of these projects towards an integrated PED. However, the replication towards other districts brings new knowledge gaps and a deeper need to study whether local smart energy systems must be integral part of a future-proof energy system in the city to achieve the climate goals.

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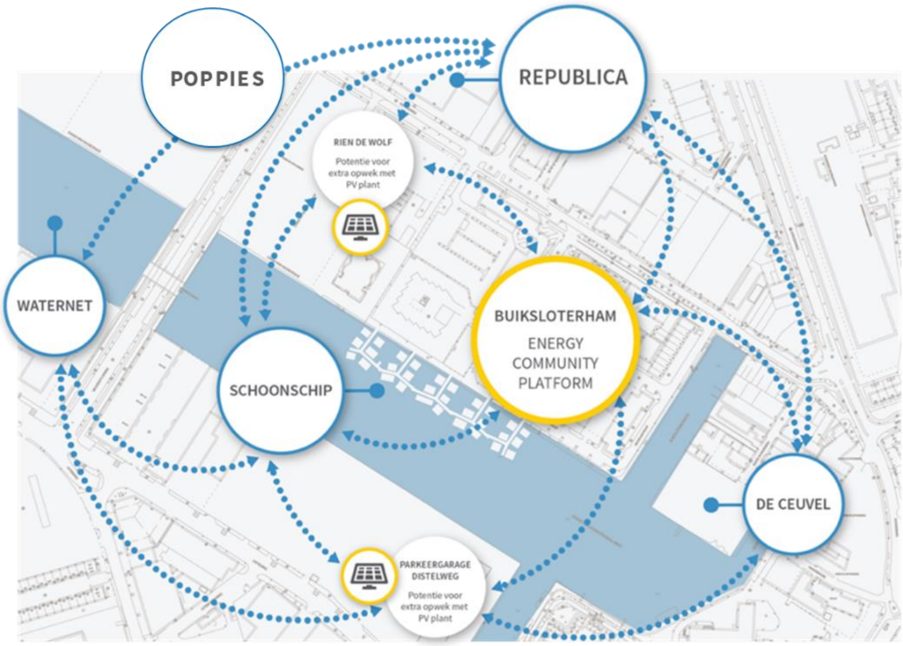

Figure 6: Buiksloterham Positive Energy District

The Atelier project is contributing to enhance the local knowledge on PEDs, however, knowledge gaps remain which mainly pertain to the replication of PEDs in Amsterdam and to be more concrete on which shape PEDs take in Amsterdam to fit with the local conditions and needs from the energy transition. The strategy of the city to increase the knowledge on PEDs and bring them closer to implementation is threefold:

1) Embedding PEDs wide and deep within the municipal organization. This entails a combination of policy, strategy and implementation, and the responsible departments within the municipality.
2) Share and disseminate the knowledge on PEDs available within the municipality towards the city.
3) Develop new knowledge related to digitalization, the relation to local energy cooperations, the matching of local energy flows, on how it tackles net congestion, the interaction between existing and new construction, the legal aspects, the roles and governance.

4.2. Bilbao

As a front runner in Cities4ZERO methodology implementation for city vision creation, Bilbao has already presented its city vision 2050 in D2.5. Therefore, in the following sections an updated version of Bilbao´s master scenario is given and the role that PEDs play in the city vision is provided.

4.2.1. Master scenario

Bilbao Master scenario is the result of the combination of alternative scenarios (also described in deliverable D2.5) which in turn include specific measures and policies. These measures

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were further mixed together according to the insights discussed with local stakeholders, resulting in the final Master scenario[8] with a 2050 horizon.

Table 3 summarises the actions considered in the 3 scenarios modelled for Bilbao: BaU scenario, alternative Scenario A and alternative Scenario B. Moreover, the specific actions selected for the master scenario are included in left part of Table 3 as well.

Table 3. Modelled measures and scenarios in the city of Bilbao.

Sector	Action field	Specific action	BaU scenario	Scenario A	Scenario B	Master Scenario (Scenario C)
Residential	Passive measures: building envelope renovation	BaU renovation rate	X		X	
		Spanish National Energy and Climate Plan renovation rate				
		City vision renovation rate		X		X
	Active measures: energy systems substitution	Natural renovation of systems	X			
		Basic electrification		X		
		High efficiency electrification			X	X
Municipal buildings	Passive measures: building envelope renovation	Low renovation rate	X			
		Medium renovation rate (Spanish National Energy and Climate Plan renovation rate)			X	
		High renovation rate		X		X
	Active measures: energy systems substitution	Natural renovation of systems	X			
		Basic electrification		X		
		High efficiency electrification			X	X
Private tertiary buildings	Passive measures: building envelope renovation	BaU renovation rate	X		X	
		Spanish National Energy and Climate Plan renovation rate				
		City Vision renovation rate		X		X
		Natural renovation of systems	X			

[8] Bilbao Master scenario mostly corresponds with Scenario C presented along with Scenarios A and B in the workshop held with local stakeholders and described in deliverable D2.5. Scenario C is indeed a combination of scenarios A and B. Nevertheless, specific assumptions were subsequently adjusted after discussion with the local stakeholders.

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	Active measures: energy systems substitution	Basic electrification		X		
		High efficiency electrification			X	X
Transport	Fleet renovation: replacement of old vehicles and penetration of EV	Municipal/public transport fleet renovation. Low rate Low penetration of EV	X			
		Municipal/public transport fleet renovation. Medium rate Medium penetration of EV		X		
		Municipal/public transport fleet renovation. High rate High penetration of EV			X	X
		Private transport fleet renovation. Low rate Low penetration of EV	X			
		Private transport fleet renovation. Medium rate Medium penetration of EV		X		
		Private transport fleet renovation. High rate High penetration of EV			X	X
	Mobility measures: access restrictions, modal changes, active mobility, public transport fostering…	SUMP	X		X	
		Drastic reduction of traffic. Increased use of public transport and active mobility.		X		X
Local energy production	Solar PV deployment in buildings	Slow solar PV deployment in municipal buildings	X	X		
		Fast solar PV deployment in municipal buildings			X	X
		Slow solar PV deployment in private buildings (residential and private)	X	X		
		Fast solar PV deployment in private buildings (residential and private)			X	X

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Table 4. Achieved energy savings in Bilbao Master scenario.

SECTOR	2018 (GWh)	2030 % reduction with regard 2018	2050 % reduction with regard 2018
Residential	839	-16%	-43%
Private tertiary buildings	739	-17%	-53%
Municipal buildings	88	-47%	-63%
Street lighting	28	-40%	-40%
Cleaning services	16	0%	0%
Municipal fleet	2	-68%	-68%
Public transport	41	-27%	-43%
Private transport	1.864	-43%	-74%
TOTAL	**3.760**	**-32%**	**-62%**

In line with the Spanish Long Term Decarbonisation Strategy[9], the decarbonisation of the national power grid has been considered by 2050. Hence, thanks to the electrification of the end-use sectors, and the penetration of other technologies (H_2 in transport, solar PV in buildings, and other renewables in buildings), carbon neutrality would be achieved by the city in 2050.

Table 5. Achieved GHG[10] savings in Bilbao Master scenario.

SECTOR	2018 (kton CO2)	2030 % reduction with regard 2018	2050 % reduction with regard 2018
Residential	203	-61%	-100%
Private tertiary buildings	196	-62%	-100%
Municipal buildings	23	-94%	-100%
Street lighting	8	-100%	-100%
Cleaning services	4	-100%	-100%
Municipal fleet	1	-100%	-100%
Public transport	9	-58%	-100%
Private transport	559	-51%	-100%
TOTAL	**1.002**	**-57%**	**-100%**

[9] https://ec.europa.eu/clima/sites/lts/lts_es_es.pdf
[10] Note that GHG emissions in all figures and tables for the Bilbao Master scenario reflect a scope 2 assessment. That is, power and heat generation emissions are allocated to the final energy consumption of electricity and heat in end-use sectors.

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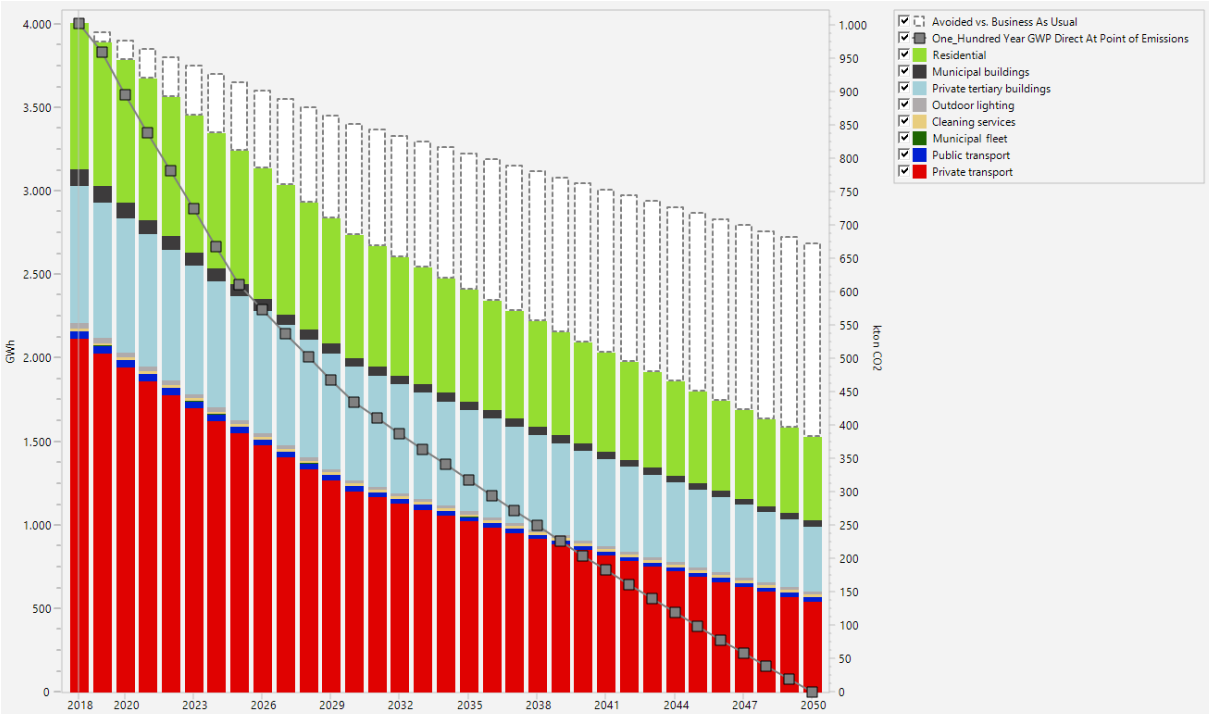

Figure 7. Bilbao energy consumption and GHG emissions by sector in the Master scenario.

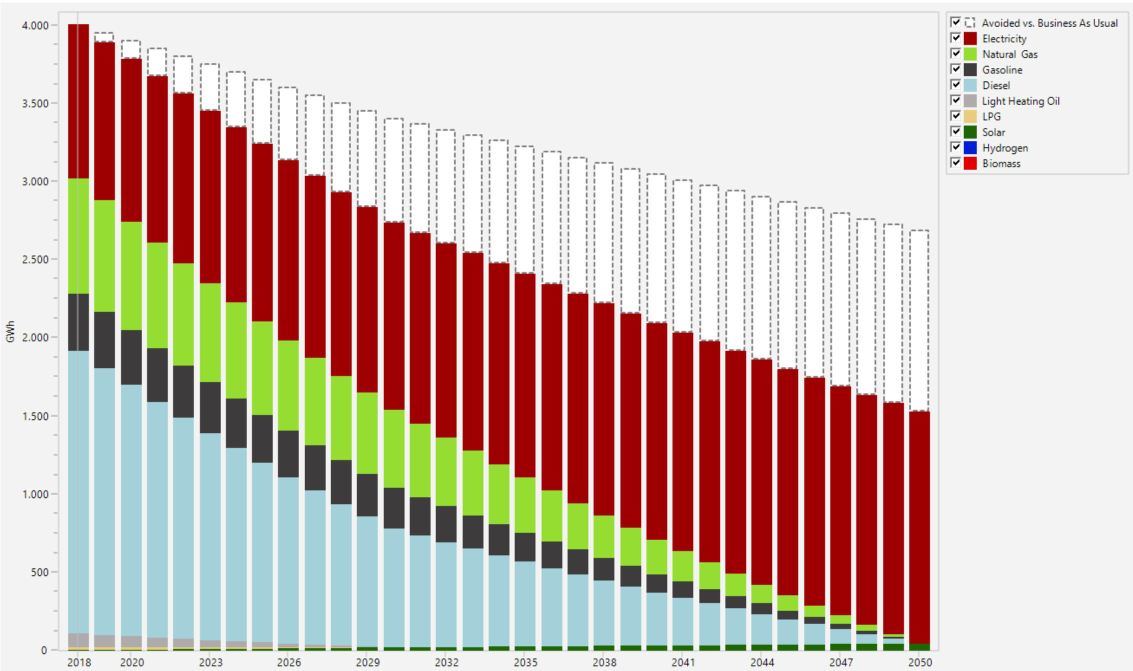

Figure 8. Bilbao energy consumption by fuel in the Master scenario.

Next sections describe the assumptions and specific sectoral results of the Bilbao Master scenario.

Residential buildings

Following the discussion on alternative scenarios with local stakeholders, for the Master scenario it was agreed that 15% of the residential building stock is renovated by 2030 and 67% by 2050. A deep high efficiency electrification of heat is assumed with the penetration of high efficiency heat pumps (e.g. hydrothermal, geothermal, low temperature rings). Contribution of solar thermal for Domestic Hot Water (DHW) slightly increased. Complete phase out of natural gas and the full decarbonisation of the national power grid achieve a carbon-free residential stock by 2050.

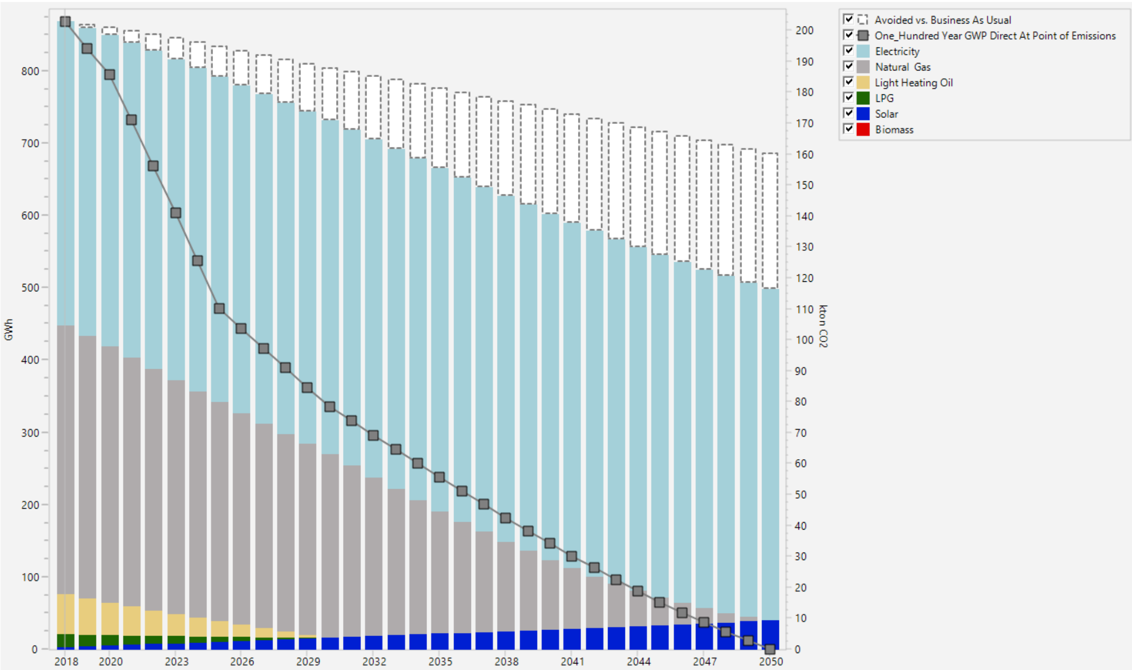

Figure 9. Residential energy consumption and GHG emissions in Bilbao Master scenario.

Private tertiary buildings

In the case of private tertiary buildings the following renovation objective was set for the Master scenario: 20% and 82% gross floor area renovated by 2030 and 2050 respectively. As for the residential sector a deep high efficiency electrification of heat is assumed with the penetration of high efficiency heat pumps (e.g. hydrothermal, geothermal, low temperature rings). Contribution of solar thermal for DHW is slightly increased. Complete phase out of natural gas and the full decarbonisation of the national power grid achieve a carbon-free sector by 2050.

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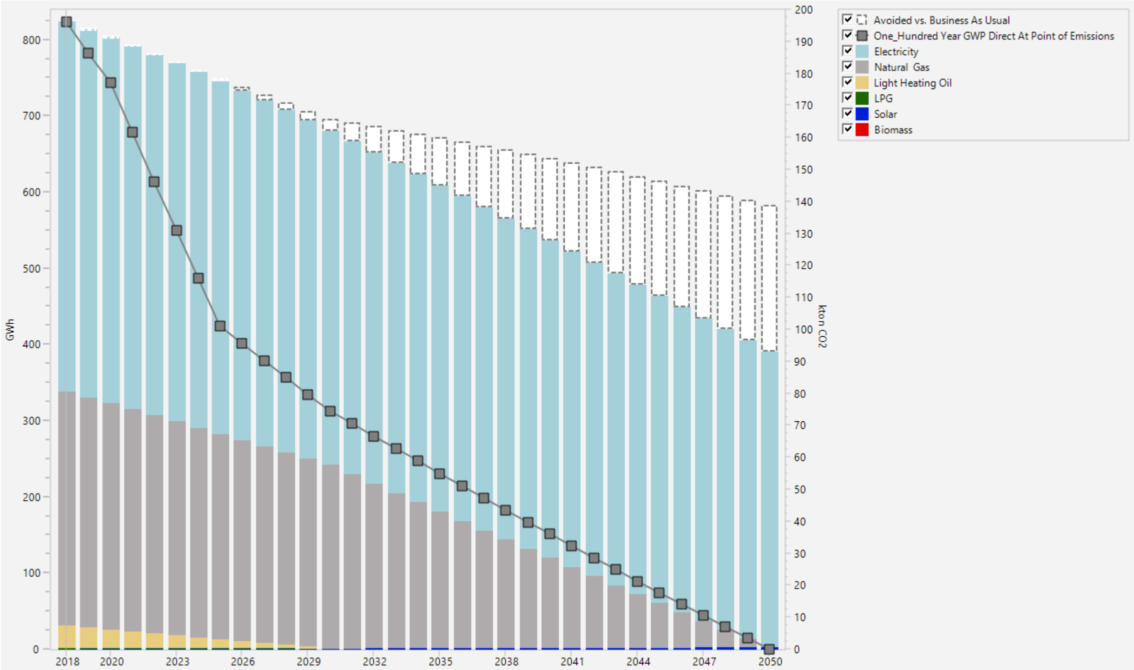

Figure 10. Private tertiary buildings energy consumption and GHG emissions in Bilbao Master scenario.

Municipal buildings

In the Bilbao Master scenario 35% of municipal buildings gross floor area is renovated by 2030, while the full renovation of the sector is achieved by 2045. As for residential and private tertiary buildings a deep high efficiency electrification of heat is assumed with the penetration of high efficiency heat pumps (e.g. hydrothermal, geothermal, low temperature rings), resulting in the complete phase out of gas by 2050. Contribution of solar thermal for DHW slightly increased. It should be noted that it is considered that since 2020 the municipality only purchases and uses green electricity (i.e. carbon-free electricity) for its assets. Therefore, GHG emissions are exclusively related to the consumption of natural gas and other fossil fuels (LPG and light heating oil removed by 2030). With the total removal of natural gas by 2050, municipal buildings are fully decarbonised by this date.

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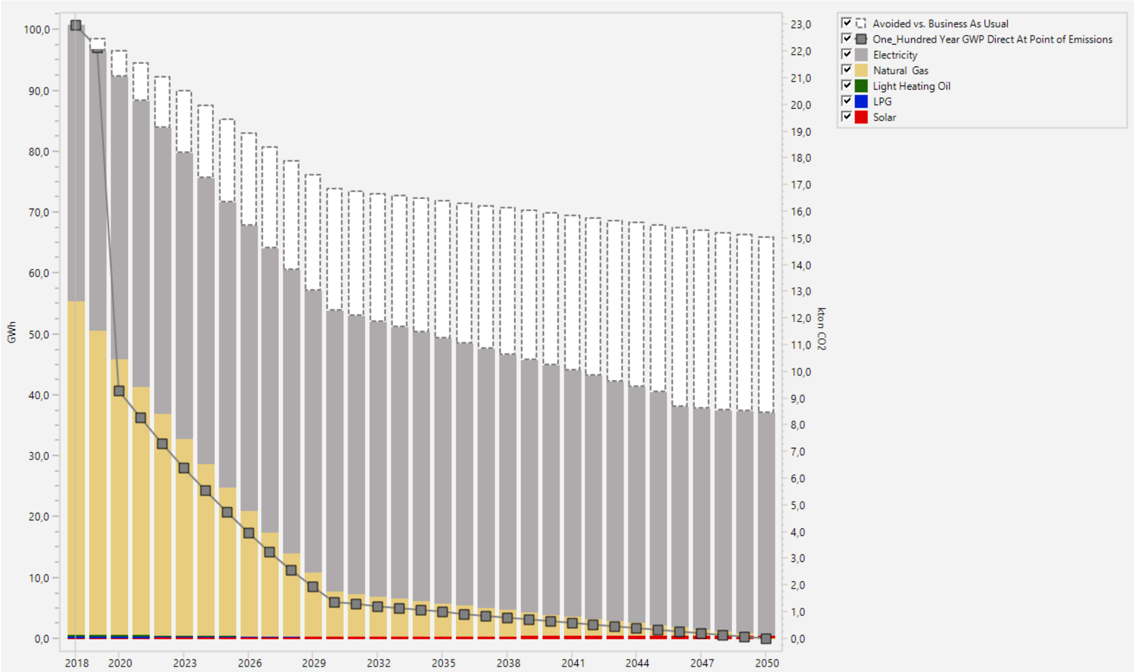

Figure 11. Municipal buildings energy consumption and GHG emissions in Bilbao Master scenario.

Street lighting

No differences with regard the BaU are considered in the Master scenario, since in the former all existing lamps are already replaced by LED lamps by 2030. As for municipal buildings, electricity supplied to municipal assets is considered to be carbon-free since 2020.

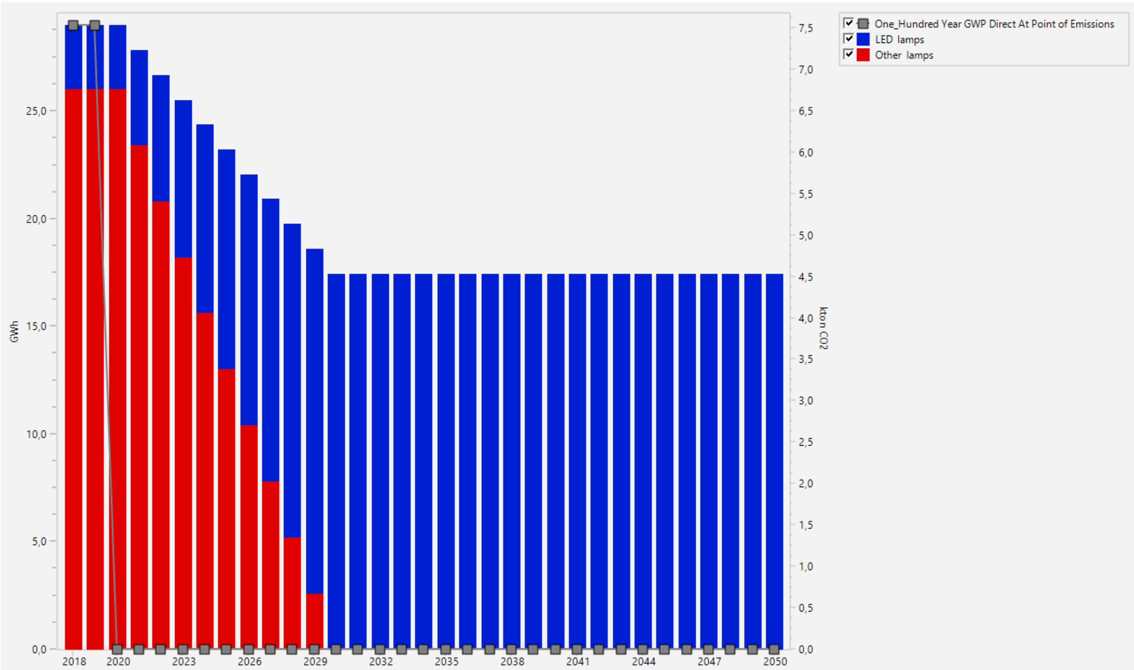

Figure 12. Street lighting energy consumption and GHG emissions in Bilbao Master scenario.

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Cleaning services

As for street lighting, no differences with regard the BaU are considered in the Master scenario. The full decarbonisation of cleaning services is achieved by 2030 when these services are electrified since electricity used for municipal assets is green-labelled since 2020.

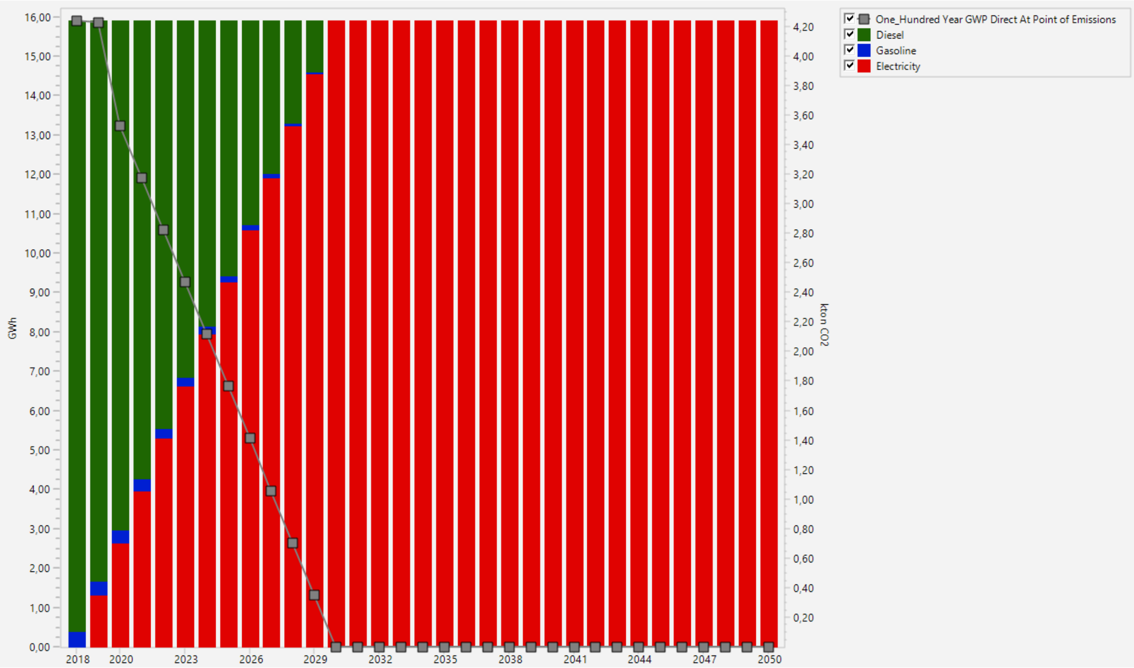

Figure 13. Cleaning services energy consumption and GHG emissions in Bilbao Master scenario.

Municipal fleet

All municipal fleet vehicles are assumed to be electrified by 2030.

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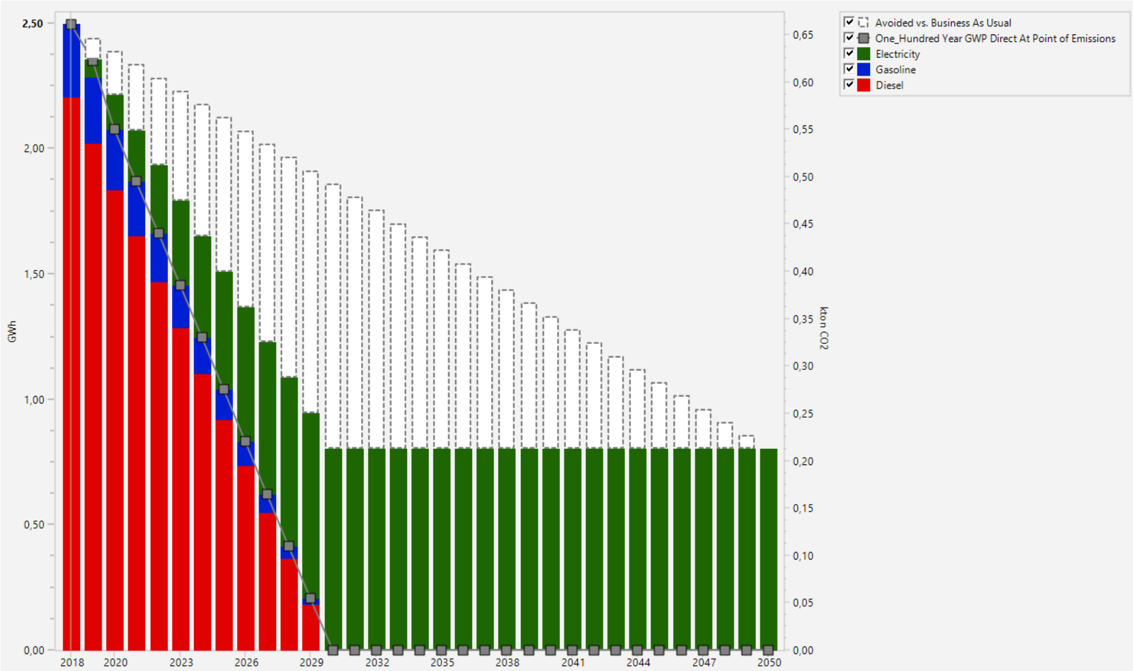

Figure 14. Municipal fleet energy consumption and GHG emissions in Bilbao Master scenario.

Public transport

Public transport in Bilbao is integrated by buses („Bilbobus") and an electric cable car („Funicular"). The demand for the latter is assumed to remain constant while the demand for the former is assumed to increase fostered by growth in the use of public transport in detriment of private vehicles (see Table 6). Along with that the whole bus fleet is assumed to be electric by 2040. As a result, the sector is fully decarbonised by this date. However, it should be noted that in energy terms, consumption is higher than in the BaU scenario because of the increase of the demand for public transport services with regard this scenario.

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Figure 15. Public transport energy consumption (by type of vehicle) and GHG emissions in Bilbao Master scenario.

Private transport

A drastic reduction of traffic and the increase of public transport and active mobility is considered in Bilbao Master scenario. Indeed, the implementation of mobility measures such as access restrictions and modal changes is modelled through the evolution of the city vehicles stock.

Table 6. Private vehicle fleet stock evolution in Bilbao Master scenario.

	2018	2030	2050
Cars	139.120	92.656	72.287
Motorcycles	21.275	22.649	23.453
Vans & light trucks	19.859	19.240	17.060
Trucks	1.581	1.366	746
Buses (private)	940	1.079	1.120
Buses (public transport)	153	184	239

In addition to the evolution of the private vehicle fleet stock, a switch between fuels used by the different vehicles has been considered.

Table 7. Fuel mix evolution by vehicle type in Bilbao Master scenario.

		2018	2030	2050
Cars	Diesel	54%	20%	0%
	Gasoline	46%	50%	0%
	Electricity	0%	30%	0%
Motorcycles	Gasoline	100%	50%	0%
	Electricity	0%	50%	100%

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Vans & light trucks	Diesel	87%	60%	0%
	Gasoline	13%	10%	0%
	Electricity	0%	30%	100%
Trucks	Diesel	99%	68%	0%
	Gasoline	1%	0%	0%
	Electricity	0%	30%	98%
	Hydrogen	0%	2%	2%
Buses (private)	Diesel	100%	68%	0%
	Electricity	0%	30%	98%
	Hydrogen	0%	2%	2%

The reduction of energy used by the private transport fleet is the result of the combination of mobility measures (which reduce the demand for private transport) and the renovation of the vehicle stock (which allows the penetration of electric and H2-powered vehicles). By 2050, Bilbao mobility is carbon-free.

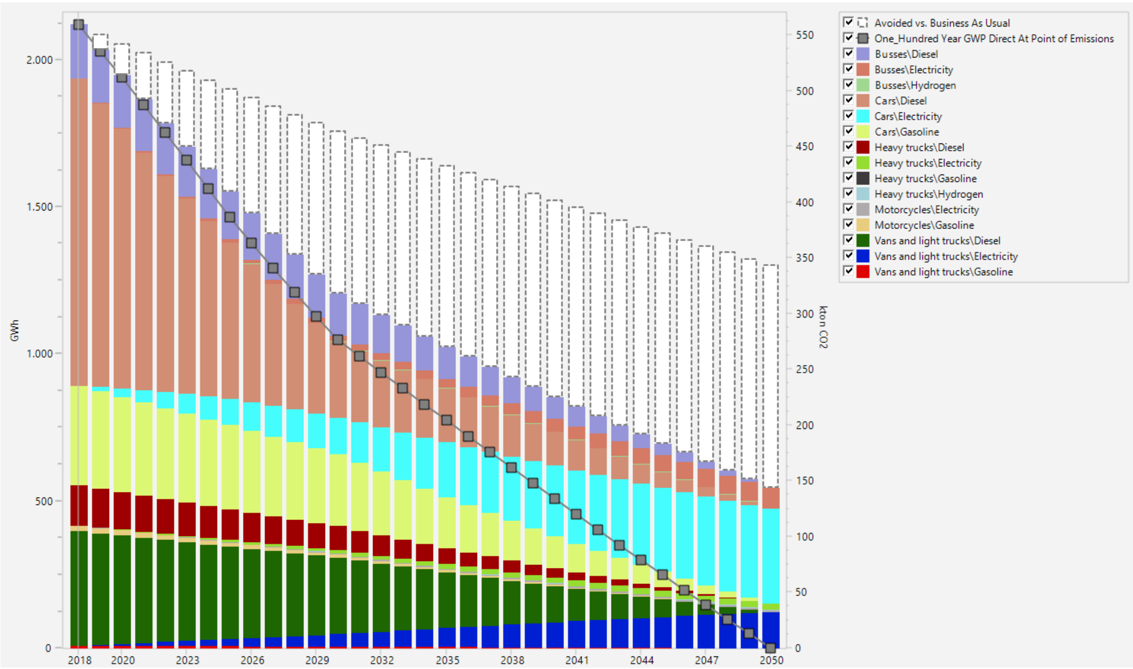

Figure 16. Private transport energy consumption (by type of vehicle and fuel) and GHG emissions in Bilbao Master scenario.

Local energy production

Bilbao does not account for a DH network, therefore only electricity is produced within the city. Indeed, electricity generated within the city comes exclusively from solar PV systems installed in buildings (see deliverable D2.5 for the city's floor area classification). For the Master scenario it has been assumed that 50% of the city total PV potential capacity is installed by 2030, and 100% by 2050. By 2050, 235 GWh are produced in the city which represents 16% of the city total electric consumption. The remaining electricity demanded in end-use sectors is imported from the national grid which by this date is fully decarbonised.

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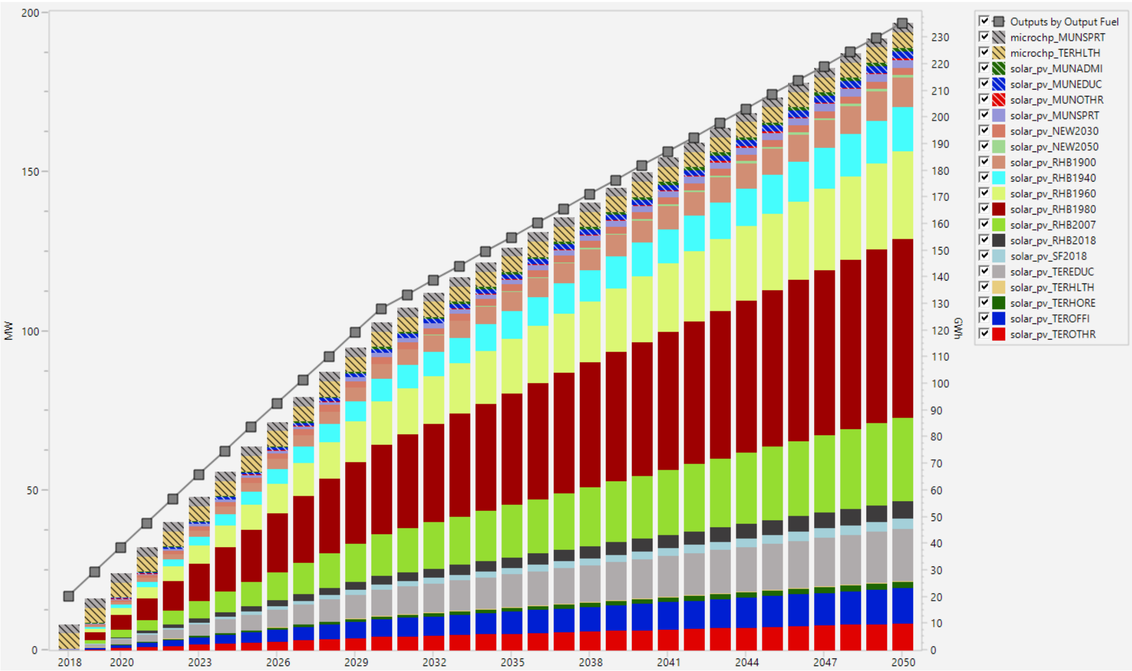

Figure 17. Solar PV installed capacity (bars) and electricity generation (dotted line) by building type in Bilbao Master scenario

4.2.2. The role of PED in City Vision

Together with Amsterdam, Bilbao is one of the cities that is implementing a Positive Energy District within ATELIER project.

The demonstration of the PED concept in the Bilbao demo-site, in the Zorrotzaurre island, has been a real challenge. From a technical perspective, a large contribution of renewable energy assets is required but additionally, a PED also results in complex urban project, involving many different actors and stakeholders and its success depends on the availability of technical solutions but also on social, political and business commitment.

Besides the relevance of acquiring successful results, a PED pilot project also offers the opportunity to gain knowledge about innovative solutions and the possibility to replicate them in other districts of the city. It is not easy either to conceive a city full of mini PEDs, but is essential to reproduce initiatives that can be integrated in the City Vision.

In the case of Bilbao, the PED is mainly supported by the deployment of a 5th generation district heating network based on geothermal exchange. This is the first district heating system in the city and consequently a key milestone that involves a great learning for the management of such big project. The aim is to examine the potential replication of such structures in other areas of the city. At first, the network will be connected with an area outside of the island to export the surplus of heat from the subsurface. At a bigger scale, City of Bilbao is defining a comprehensive plan of the heating and cooling supply with the intention of selecting most suitable strategies for the phase out of fossil fuels in each district of the city. Several energy,

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urbanistic and building configuration criteria are considered for these analysis. For instance, potentially areas nearby to the estuary could be connected to a DHN based on the heat exchange with the river and certain points from the business model in Zorrotzaurre could be adopted.

4.3. Bratislava

4.3.1. Process followed for city vision development

Bratislava 2030

Bratislava has linked its sustainable development strategy to the Agenda for Sustainable Development 2030, a plan adopted by 193 UN members in 2015. Bratislava 2030 with the subtitle City Development Plan 2022-2030 is a strategic document that you may also know under the older name Economic and Social Development Scheme (ESDS).

Bratislava 2030, https://bratislava2030.sk/en/agenda-2030/, is a key document for the management of local government. It identifies challenges and defines goals and priorities for future development. At the same time, it provides a set of tools and measures that will enable local government to achieve the objectives.

The document consists of three parts:

- Bratislava Vision describes the overall vision of the city's development. It briefly introduces strategic planning and shows how we created the plan. The readers will also be acquainted with the methods of its implementation and financing.
- The analytical part contains a comprehensive assessment of the city's baseline situation. The topics of the analytical section follow the structure of local government competencies. It is based on 11 topics that follow the structure of local government competencies. We build on these starting points in the strategic part through strategic and specific objectives.
- The strategic part contains the city's development strategy, with reference to its internal specificities. It determines the main direction, priorities, and objectives of the city's development with respect to principles of regional policy to achieve a balanced and sustainable development of the city and the quality of life for its inhabitants. There is also information on the plan section, which mainly contains a list of measures and activities to ensure the implementation of the city development scheme.

The plan is based on the application of four principles:

- Internal processing, which ensured intensive involvement of the city's expert capacities, either directly from the city or municipal organizations. The aim was to link strategic planning to the city's internal processes.
- Involvement of the general, organized, and professional public through public meetings (Metropolitan Forums), surveys, workshops, and especially meetings of Working Groups. Those were composed of the senior or professional staff of the city, city districts, and organizations, as well as third-party experts.
- Taking into account the Sustainable Development Goals as defined in the international document 2030 Agenda.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 864374.

- Setting up the monitoring system. Measurable indicators are linked to the objectives. They will enable us to effectively monitor how we are meeting the targets.

To ensure the implementation of the 2030 Agenda's principles, as well as methodological support for the development of a functional strategic plan, the Capital City of the Slovak Republic, Bratislava, is involved in the European Commission's URBACT scheme through the Metropolitan institute of Bratislava. Specifically, the project named Global Goals for Cities.

Global Goals 4 Cities (GG4C) is a strategic partnership of 19 EU cities focused on localizing, implementing, and achieving the Sustainable Development Goals.

This partnership provides support to cities in the form of training, knowledge, and know-how in the field of integrated action planning. The partnership is funded through the URBACT III scheme of the European Regional Development Fund's European Territorial Cooperation Program. It provides methodological support in defining the vision, strategic objectives, setting indicators and developing an action plan for the new strategy document Bratislava 2030.

Important current projects that support the development of the city's decarbonisation strategy:

Climate resilient Bratislava – Pilot project for decarbonisation, energy efficiency of buildings and sustainable rainwater management in urban space.

This project is implemented under the **Programme Climate Change Mitigation and Adaptation**. On the basis of the Memorandum of understanding on the implementation of the European Economic Area Financial Mechanism 2014-2021 (EEA FM) and the Memorandum of understanding on the implementation of the Norwegian Financial Mechanism 2014-2021 (NFM), the Ministry of Environment of the Slovak Republic is designated as the Operator of this Programme.

The programme objectives and outcomes are defined in line with the current national strategies and challenges, as well as examples of good practice of the programme "Adapting to climate change and preventing floods and droughts 2009-2014" (e.g. "Blue School", "Healthy Cities"). The following results and outcomes are defined within the Programme SK-Climate:

- Action plans for mitigation and adaptation to climate change implemented by local authorities in urban areas" (2 calls, funded by the EEA FM/NFM)
- Awareness raising activities on climate change mitigation and adaptation carried out by schools" (Small Grants Scheme - 1 call, funded by the NFM)
- Awareness raising activities on climate change mitigation and adaptation" (1 call, funded by the NFM)
- Restoration of degraded wetland ecosystems (1 call, funded by the NFM)

Decarb City Pipes 2050 is the first project to unite cities across Europe to work out actionable, spatially differentiated transition roadmaps to decarbonise heating and cooling for buildings in 2050. Bilbao, Bratislava, Dublin, Munich, Rotterdam, Vienna and Winterthur are taking up the challenge of phasing out natural gas in heating. Recent Bratislava city strategies focus primarily on smart city solutions, sustainable transport and mobility, minimising the carbon footprint of the city. Special attention is given to housing and buildings refurbishment, waste treatment sectors, implementing green and soft adaptation measures to maximise the use of rainwater and green infrastructure. Bratislava has extensive district heating grids, but very little of it sourced by renewable energy, and it hopes to build up capacity for the heating and cooling

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transition with Decarb City Pipes 2050. Bratislava also hopes to use lessons learned from this project in the update of its heating concept due in 3-4 years. Results from this project will be incorporated in its SECAP 2030 – Sustainable Energy & Climate Action Plan for the Covenant of Mayors.

Important documents for the preparation of the City Vision:

SEAP The Sustainable Energy Action Plan of the Capital City of Bratislava (formulated in 2013) is a comprehensive short- and medium-term strategic document that defines the city's activities aimed at reduction of CO2 emissions. It has been developed in connection with the city's accession to the EU-wide **Covenant of Mayors** initiative.

As a starting point for the elaboration of the Action Plan, based on the overall vision of the city set out in the Economic and Social Development Programme of the Capital City of the Slovak Republic Bratislava for 2010 - 2020, the vision of Bratislava's sustainable development in the field of energy and the fight against climate change is as follows:

Bratislava, aware of the impacts of activities in the city on the climate, will, when its development and improving the quality of life of its inhabitants and visitors, take an active and responsible approach to reducing greenhouse gas emissions in its territory in order to contribute to the preservation and improvement of the environment in the city as well as in neighbouring areas.

From a thematic point of view, the SEAP focuses in general on the following sectors:

- Buildings (Public Buildings, Residential, Tertiary)
- Transport

At the same time, it is also recommended to follow the following areas:

- Local energy production
- Spatial planning
- Public procurement
- Working with citizens and other stakeholders

SECAP 2030: sustainable energy and climate action plan- reduction of emissions CO2 by 40% up 2030.

The Bratislava municipality is currently preparing its SECAP according to the following objectives:

1. Creation of the SECAP document as a strategic document: defining adaptation and mitigation measures with aim of reducing emissions by 2030
2. Participation of all concerned city departments, citizen involvement and stakeholders
3. Analytical part - evaluation of the current situation in Bratislava:
    - energy consumption & emissions inventory
    - assessment of risk and vulnerability to climate change
4. Proposal of strategies and specific measures until 2030 linked to key sectors and activities
5. Funding sources - proposed measures must be included in the city's investment plans
6. Mass media communication - raising environmental awareness

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EU Mission on Climate-neutral and Smart Cities

The city of Bratislava has been selected as one of the cities in a European Union Mission - 100 climate-neutral and smart cities by 2030.

The plan is to use this initiative to systemise climate, decarbonisation and sustainability agendas and to link activities that the city carries out on its territory more intensively, with the aim of achieving the maximum possible CO_2 savings with the effective use of available resources, specified the capital. By 2030, it aims to achieve a 55% cut in CO_2 emissions in tonnes. It admitted that the target may be set more ambitiously later.

Bratislava will draw up a "Climate City Contract" by the beginning of 2024. This will be a decarbonisation plan in five main areas and at the same time a plan for cooperation with relevant parties. The five main areas, which are the largest sources of greenhouse gas emissions, are stationary energy (all buildings and premises in the city); transport; waste/a circular economy (energy required for waste removal and processing, gases produced during the decomposition of solid waste); agriculture, forestry and other land use; and industrial processes and product use.

4.3.2. City Vision

When creating City Vision, we expect that after the completion of action plan SECAP, we will have processed the current state of production of greenhouse gas emissions produced by all sectors in the city. At the same time, this action plan will present possible mitigation measures for reducing the production of emissions. We expect the SECAP to be ready in spring 2024, and then the proposed measures and GHG reduction plans can be incorporated into the City Vision strategy.

We also expect that the whole process will be accelerated by other factors, the newly emerging Department. climate change will be complemented by the SCPG team, the project of 100 climate neutral cities and the CCC contract will oblige Bratislava to become climate neutral by 2030, and will contribute to the creation of other scenarios.

The main barriers that have been identified so far are missing data or lack of data, especially from the construction sector, but also a lack of experts. These barriers will potentially be overcome in the near future. For example, the preparation of SECAP will help with data collection, and the Innovation Atelier will involve experts from the main areas important for the energy transformation, as described in the Quadruple Helix model. After solving the mentioned barriers, together with experts involved in IA, we can analyze and prepare a plan to replicate the PED concept not only in Bratislava, but also support other cities.

4.3.3. Energy and environmental diagnosis update

In the case of Bratislava, no scenarios could be developed due to the current unavailability of data. Altough the city diagnosis has been improved with new information with regard to the previous version in deliverable D2.5, the input to the model is not consistent nor complete enough to perform a (to the extent possible) rigorous prospective assessment and to generate useful scenarios.

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Building (residential, municipal, and private tertiary buildings) energy consumption data has been updated, including electricity information which was missing in the previous version. Industry data has also been completed and disaggregated by fuel type. However, updated enegy consumption related to public lighting and transport (municipal, public transport, and private transport) is still missing and had to be filled with the latest available data (2005) from the previous city SEAP (2013)[11]. Finally, regarding local energy production, additional data has been extracted from the city heat plan[12], though information regarding power generation and the fuels and quantities used for heat production is still lacking. The city should therefore make an effort to update the values of these sectors, so the model may be correctly and homogenously calibrated, defining a coherent baseline from which a coherent prospective analysis starts.

Table 8. Bratislava base year (2017) energy consumption (in GWh) by fuel.

SECTOR	Electricity	Heat	Natural gas	Coal	Coke	Biomass	Biogas	Waste	Gasoline	Diesel	Other petroleum products	TOTAL
Residential	423	1.239	787	3	0,2	16	0	0	0	0	0	**2.468**
Private tertiary buildings	879	231	1.040	0	0	0	0	0	0	0	0	**2.150**
Municipal buildings (2013)	15	15	23	0	0	0	0	0	0	0	0	**53**
Street lighting (2005)	20	0	0	0	0	0	0	0	0	0	0	**20**
Industry	0	49	5.628	0	535	16	10	420	0	0	7.197	**13.856**
Municipal fleet (2005)	-	-	-	-	-	-	-	-	-	-	-	**-**
Public transport (2005)	49	0	30	0	0	0	0	0	0	229	0	**308**
Private transport (2005)	0	0	0	0	0	0	0	0	859	1.965	29	**2.852**
TOTAL	**1.387**	**1.533**	**7.478**	**3**	**536**	**32**	**10**	**420**	**859**	**2.194**	**7.226**	**21.708**

Regarding emission factors, it was impossible to determine local heat and electricity emission factors since data regarding the technologies nor quantities of fuels used for power or heat generation was available. Therefore, the last factors from the city SEAP (2013) were used[13].

Table 9. Bratislava base year GHG emissions (Scope 2).

SECTOR	2017 (kton CO2)
Residential	593
Private tertiary buildings	491
Municipal buildings	12

[11] https://mycovenant.eumayors.eu/docs/seap/4499_1392205965.pdf
[12] https://bratislava.blob.core.windows.net/media/Default/Dokumenty/Koncepcia%20Bratislava%20-%20doplnenie%2005_18.02..pdf
[13] 0,25 ton CO_2/MWh and 0,26 ton CO_2/MWh for electricity and heat respectively.

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Street lighting	5
Industry	3.819
Municipal fleet	-
Public transport	80
Private transport	745
TOTAL	**5.745**

Next are described the assumptions and specific sectoral values of the updated diagnosis for the city of Bratislava.

Residential buildings

Residential buildings in Bratislava have been clustered by construction period. Moreover, two main energy services have been defined: heating use and electric use. For every construction period a specific consumption for each energy service has been defined using information contained in the city heat plan[12] as a reference. Regarding fuel distribution it has been assumed that solid fossil fuels (i.e. coal and coke) are not used in the newest buildings. In absence of further information, the rest of fuels have been equally distributed amongst all buildings.

Table 10. Characteristics of Bratislava residential stock by construction period.

<table>
<tr><th rowspan="2">Construction period</th><th rowspan="2">Gross floor area (m^2)</th><th rowspan="2">Heating uses specific consumption (kWh/m^2)</th><th colspan="5">% for heating uses</th><th rowspan="2">Electric uses specific consumption (kWh/m^2)</th></tr>
<tr><th>DH</th><th>Natural gas</th><th>Coal</th><th>Coke</th><th>Biomass</th></tr>
<tr><td>Pre 1919</td><td>280.443</td><td>171,23</td><td rowspan="10">60,57%</td><td rowspan="7">38,47%</td><td rowspan="7">0,15%</td><td rowspan="7">0,01%</td><td rowspan="10">0,79%</td><td rowspan="10">25,99</td></tr>
<tr><td>1919-1945</td><td>1.255.746</td><td>165,78</td></tr>
<tr><td>1946-1960</td><td>1.750.318</td><td>165,78</td></tr>
<tr><td>1961-1970</td><td>2.552.117</td><td>165,78</td></tr>
<tr><td>1971-1980</td><td>3.852.760</td><td>108,77</td></tr>
<tr><td>1981-1990</td><td>2.946.597</td><td>103,80</td></tr>
<tr><td>1991-2000</td><td>958.855</td><td>103,80</td></tr>
<tr><td>2001-2005</td><td>578.952</td><td>102,98</td><td rowspan="3">38,64 %</td><td rowspan="3">0%</td><td rowspan="3">0%</td></tr>
<tr><td>2006-2010</td><td>1.021.841</td><td>102,98</td></tr>
<tr><td>Post 2010</td><td>1.068.392</td><td>81,16</td></tr>
</table>

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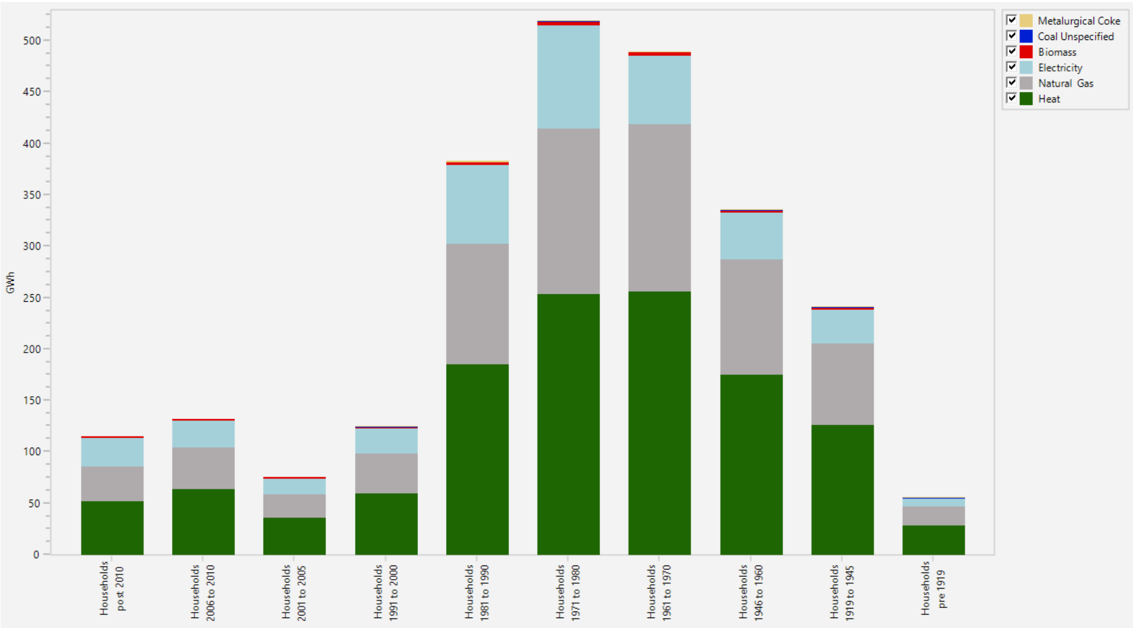

Figure 18. Bratislava residential building stock energy consumption (by construction period and fuel) in the base year.

Private tertiary buildings, municipal buildings, and street lighting

Tertiary sector in Bratislava gathers private tertiary and municipal buildings, and street lighting. Although new data has been available, data should be improved to accurately disaggregate the overall consumption of the sector provided by the city. Indeed, data regarding municipal buildings and public lighting has been extracted from outdated sources (2013 SEAP).

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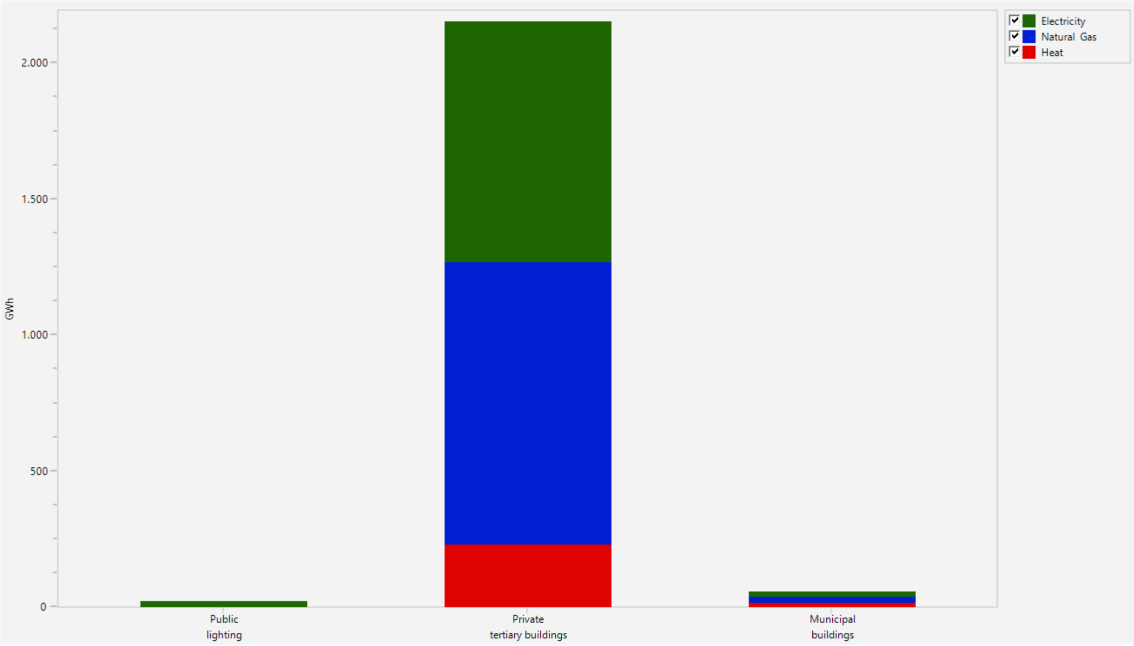

Figure 19. Bratislava tertiary sector energy consumption (by subsector and fuel) in the base year.

Industry

Data from industry has been improved with relative to the previous version, allowing the break down by fuel.

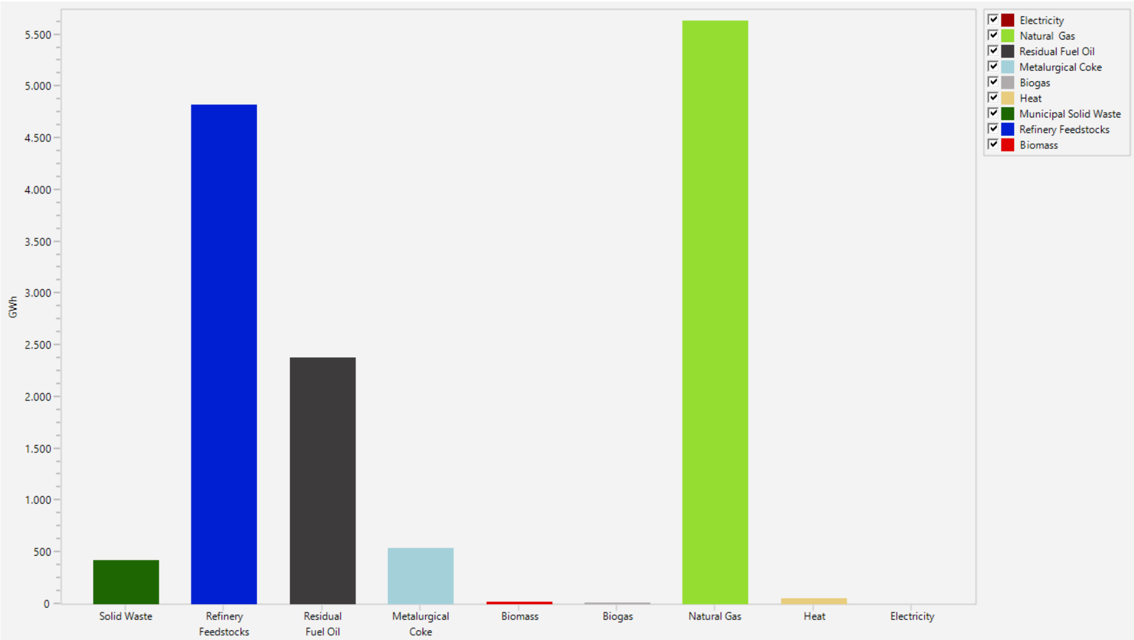

Figure 20. Bratislava industry energy consumption by fuel in the base year.

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Municipal fleet and public transport

No data regarding municipal fleet has been provided. Concerning public transport energy consumption, information contained in the 2013 SEAP has been used to characterise the consumption of buses, trams, and trolleys trough the definition of energy intensities adjusted to the total energy consumption by fuel reported in the document. This data should be revised and updated.

Table 11. Bratislava public transport vehicles characteristics.

Type of vehicle	pkm	Final energy intensity (MWh/vehicle)
Diesel buses	25.553	8,97
CNG buses	2.839	10,58
Tram	8.464	3,38
Trolleybus	6.041	3,38

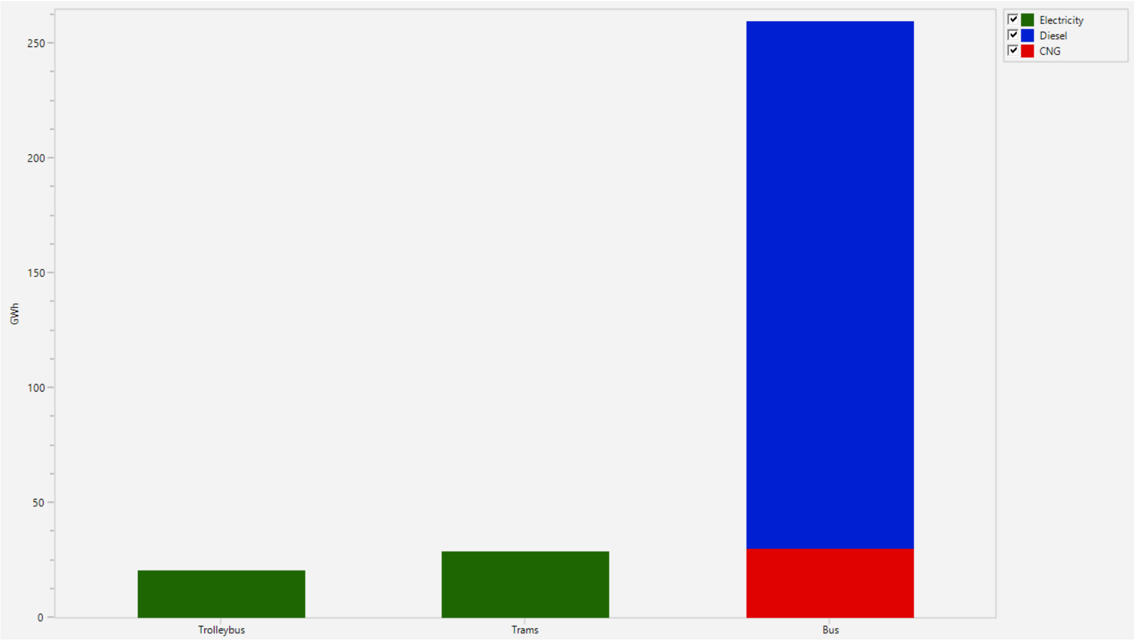

Figure 21. Bratislava public transport energy consumption (by type of vehicle and fuel) in the base year.

Private transport

Characterisation of the private transport has been revised with regard the previous version. Although outdated, information contained in the 2013 SEAP (see Table 12) has been used to characterise the consumption of the different types of vehicles through the definition of energy intensities adjusted to the total energy consumption by fuel reported in the document (see Table 13). On this concern it should be noted that given that consumption and vehicle stock data refer to different years (2005 and 2017 respectively) inconsistencies may arise (e.g. inconsistent mileages or MWh/vehicle intensities) since urban mobility has probably changed since the draft of the last city SEAP. Therefore, the city should revise and update the figures regarding transport consumption.

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Table 12. Transport fuel consumption reported in the 2013 Bratislava SEAP.

Vehicle type	Fuel	Fuel consumption (ton)	Energy consumption (MWh)
Two wheels	Gasoline	132,29	29.081
Cars	Diesel	32.056,63	385.570
	Gasoline	66.538,07	29.182
	LPG	2.220,55	828.029
Light utility vehicles	Diesel	3.505,27	42.161
	Gasoline	2.336,84	29.081
Trucks	Diesel	127.772,8	1.536.823

Table 13. Bratislava private vehicles stock characteristics.

Vehicle type	Fuel	Nº vehicles	kWh/km	Km/vehicle	MWh/vehicle
Two wheels	Gasoline	15.936	0,40	258	0,10
Cars	Diesel	97.136	0,67	5.941	3,97
	Gasoline	191.328	0,70	6.193	4,33
	LPG	5.886	0,83	5.941	4,96
Light utility vehicles	Diesel	24.397	1,06	1.626	1,73
	Gasoline	16.265	1,07	1.670	1,79
Trucks	Diesel	28.793	2,24	23.796	53,37

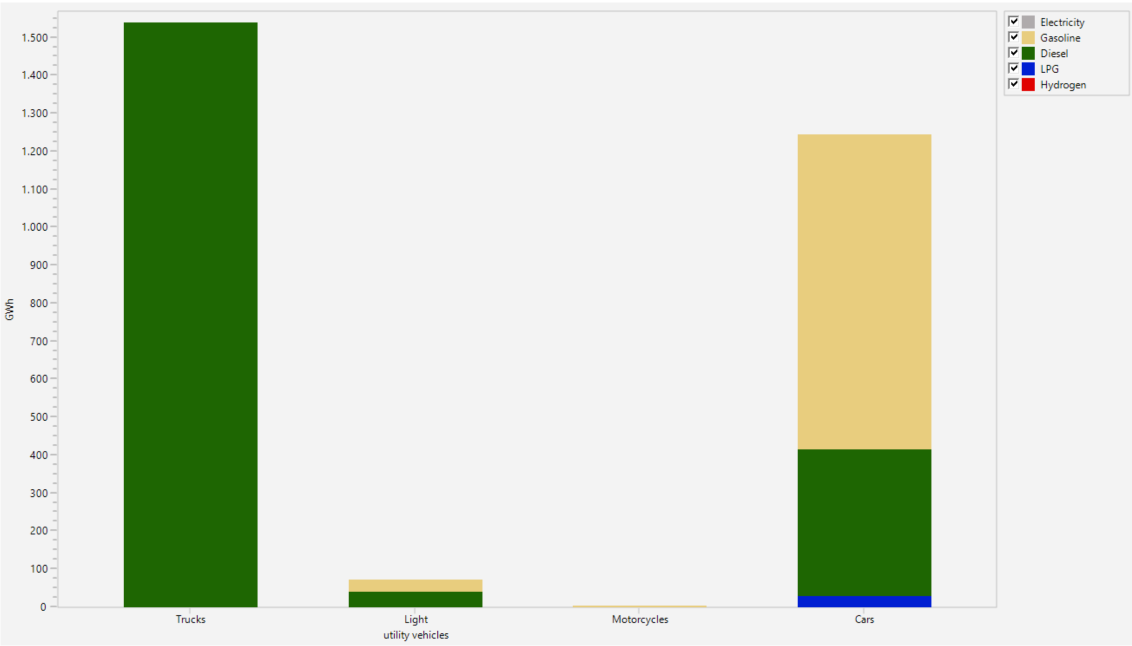

Figure 22. Bratislava private transport energy consumption (by type of vehicle and fuel) in the base year.

Local energy production

Bratislava accounts for a DH network which supplies heat to buildings and industry. Total heat generation for 2017 has been provided, whereas installed capacity of boilers and CHPs plants has been extracted from the city heat plan. Nevertheless, no information regarding fuel consumption in boilers and CHPs nor other electricity generation has been issued, making it

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impossible to define updated local electricity and heat emission factors (the ones from the last 2013 city SEAP have been used as commented previously). Other local electricity production plants than CHPs have not been detailed either. The city should work on gathering this information.

Table 14. Bratislava local energy production in the base year.

Energy vector	Installed capacity (MW)	Generation (MWh)
Heat production	1929,73	1.533.261
Electricity production	63,99	-

4.3.4. The role of PED in City Vision

Bratislava understands PED as a concept to connect challenges and planning at the level of buildings and cities. PEDs are energy-efficient and energy-flexible urban neighborhoods that produce zero greenhouse gas emissions and actively manage an annual local or regional surplus of renewable energy production. They require the integration of various systems and infrastructures and the interaction between buildings, users and regional systems of energy, mobility and information and communication technologies, while optimizing the habitability of the urban environment in accordance with social, economic and environmental sustainability.

When creating the concept of the first PED in Bratislava, we involved students in cooperation with FAD STU, who created the first designs of urban structures (according to Quadruple Helix principles, with members from industry, academia, society and city government). This process took place in the second half of 2022. It generated the first considerations about the possibilities of the selected greenfield, about the setting of the mix of functions, the use of RES, and about the limitations of the given location.

The further development of the PED will follow on from the winning architectural competition for the neighborhood adjacent to the considered PED, the effort will be to connect to the design won by the well-known Slovak architectural studio BKPŠ architekti with whom we concluded a cooperation agreement. The competition was announced by MIB in 2021.

These inputs will become an important part of the Innovation Atelier team of experts who will define the next step for the first PEDs, to create a valuable and beneficial first PED concept for the city.

PED is ultimately seen in Bratislava as a solution to urban decarbonisation, helping to balance the grid as well as improve the quality of life for residents. The European Commission states that the ambition of the PED is to "go well beyond what is already required in the Energy Performance of Buildings Directive".

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Their goal is to combine goals and tools from several disciplines to achieve a high quality of life with efficient use of space and resources and enable sustainable and resilient operation and use. They can flexibly interact with the surrounding energy system, consuming more energy when there is an excess of renewable resources and less when there is a deficit. They achieve this by using intelligent building management systems and by taking into account the behavior and needs of users and residents and actively incorporating them into the planning and development of urban neighborhoods.

Bratislava realizes that any system can only last if it is supported by users and residents. This means actively involving them and letting them participate where possible and this could take the form of surveys, co-decision on key issues, organizing events to shape and develop the identity of the space, etc. Therefore, these processes will also follow the process of creating the concept of the first PED, because the requirements for energy supplies and the resulting emissions are facts that will shape our society in a fundamental way, they will need to be explained to residents and users.

4.4. Budapest

4.4.1. Process followed for city vision development

The Smart City Planning Group (SCPG) is a versatile and flexible local coordination team established under the Cities4ZERO methodology. Its role is to ensure an appropriate governance structure for the development and execution of a City Vision. The formulation of such an expert group was tasked within the Atelier project. However, since Budapest already had a very similar consortium built, it decided to keep using them, instead of formulating an almost identical group.

The Budapest SCPG is rather an informal group coming from previous works, such as the Climate Strategy or SEAP and SECAP development. The Municipality of Budapest regularly asks citizens' opinions in various surveys, both of a representative nature, as well as informally, via mini questionnaires placed on the website. Both took place when developing the Climate Strategy and SECAP, as well as the Integrated Urban Development Strategy. These serve as a good basis for the city vision creation, since there were specific questions related to the respondents' preferences and future vision of the city.

The SCPG was founded in 2020 and is fully operational since then, while being periodically updated. The source of funding for the group comes from municipal and European funds. It consists of well-qualified and experienced professionals from different areas of the municipality, such as mitigation, adaptation, energy, retrofitting, urban and spatial planning, city management dealing with public utility services, public procurers, and project managers. While this group fulfils its roles in the project, it is not fully dedicated to energy transition and decarbonization topic. The following picture shows the Budapest SCPG structure:

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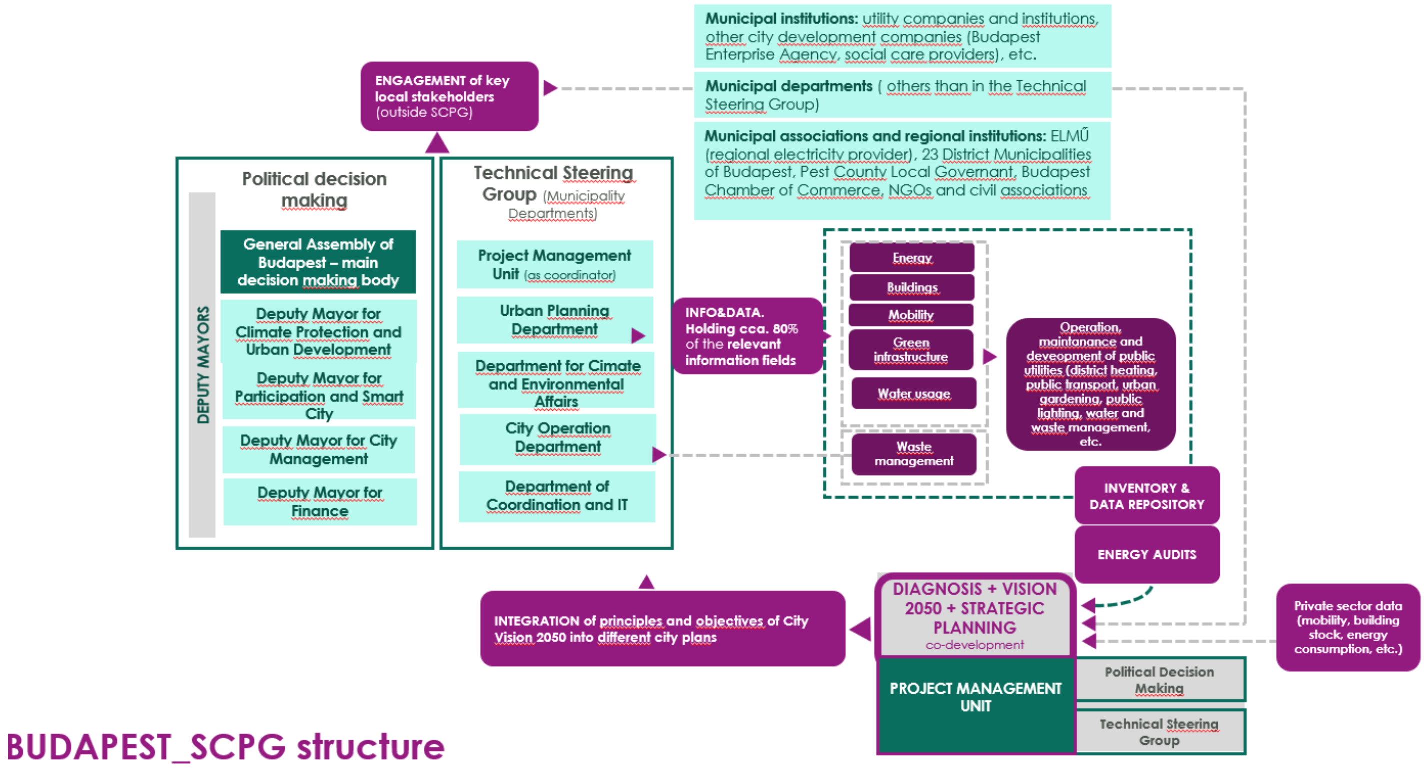

Figure 23. Budapest SCPG structure (Source: D2.2 Report on Smart City Planning Groups (SCPG)).

Budapest SECAP-2030

The 2021 Budapest SECAP revision used a very similar methodology to Cities4Zero, and set the goals to be achieved by 2030. For Budapest, SECAP collects the main goals and targets of the City vision. The mandatory revision of the document is in every two years, and this time, with input from ATELIER, we are expanding the goals to be achieved for 2050, and align it with 100 Climate Neutral Cities mission (as Budapest is one of the selected Mission Cities). The Municipality has already formulated a new group in charge of the revision process, and the data collection has already begun. Tecnalia provided input in adjusting the goals from 2030 to 2050, and showcased a scenario where rather than 40% emission reduction, by 2050 Budapest would reach carbon neutrality.

Budapest CCC

Budapest has joined the "100 Climate-Neutral and Smart Cities by 2030" Mission, where it has started to set up the Transition Team, a governance body to achieve the 2030 climate neutrality targets. The Transition Team is led by the Municipality of Budapest and aims to bring together the stakeholders of the net zero targets: companies, NGOs, academia, etc. The result of this joint work will be the City Climate Contract (CCC), which will set out the stakeholders' commitments, sector by sector, with the necessary investments and financing needs. Although the document is not legally binding, it will be a strong declaration of intent by the signatories to achieve the objectives. Therefore, we aimed to align Budapest’s city vision with the goals set out in the CCC.

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Budapest ASCEND

Budapest is a beneficiary of a HORIZON Europe project called ASCEND[14], which focuses on Positive Clean Energy District development. The city will build on the knowledge gained from ATELIER (as they are both Horizon projects about PEDs) to develop a Positive Clean Energy District (PCED) in the city's 4th District. The role of ATELIER and the vision we set for Budapest within it will be greatly represented through this horizon project. For a while, the two projects will run simultaneously, therefore we are putting extra effort into channelling information gained, into it and vice versa. The Atelier PED replication plan will be a very significant document in helping us shape future PEDs and ASCEND project in Budapest.

City vision co-development process: methodology applied in the City of Budapest

The development process can be summarized in five steps:

I. Foundation of local SCPG – Budapest uses the same Climate Platform (originally established for the SECAP development phase back in 2017) for various projects, each time with slightly adjusted participants. It's a trusted board of experts who have provided input for many projects before. Therefore, it was much easier to gather them and discuss the issues at hand.

II. City information gathering – since the city already had a SECAP, the data used there could be applied here as well. Any new data came from the Central Statistical Office

III. Strategic City Diagnosis – again, a SWOT analysis has already been done for our SECAP, which was used and expanded by the core Atelier team, so that it focuses on the 2050 energy city vision.

IV. Strategic planning – Possible narratives were drawn up with the help of Tecnalia, aiming at achieving the 2040 vision goals. Finally, we have agreed upon a Master Scenario, which incorporates SECAP until 2030, and presumes a carbon-free future by 2050.

V. Plan – the final goal is to have a revised SECAP 2030 with possible aims for 2050.

We faced and will continue to face barriers to this process. Due to a volatile environment, we must deal with new challenges and changing circumstances regularly. There is also a general lack of data. We would need continuous monitoring, new methodologies to measure, reorganize and automate data collection, and find a way for faster data processing procedures. Finally, with missing financial and state support, we will face difficulties with the implementation of the results.

We have identified three main facilitators to this development process. First, the stakeholder's involvement, which helped us to grasp the local knowledge and approach of the topic experts. Secondly, municipal commitment, which provided us a supportive environment to deliver effective action plan on a long term. Finally, the committed leadership of the city, because to achieve such ambitious goals, it requires political will and appropriate city governance.

4.4.2. City Vision

In Budapest, the municipality already has a SECAP 2030, which they intend to extend to a SECAP 2050 through the co-creation of the Budapest Vision 2050. This approach is unique among ATELIER cities, extending the strategic planning approach of SECAPs from 2030 to

[14] https://www.ascend-project.eu/

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2050. According to our currently active SECAP, the city planned to have reduced emissions by 40% until 2030. However, in 2023, Budapest joined the "100 Climate-Neutral and Smart Cities by 2030" Mission, by which the city intends to achieve climate neutrality by 2030. The CCC is emphatically not a legally binding, but a political document. First and foremost, it is the revelation of political intent and commitment. The selected cities are primarily experimental and innovation centers, where solutions for urban decarbonization efforts are sought in a holistic approach. The City of Budapest put the improvement of residential energy efficiency as their primary objective, as this sector is responsible for the largest carbon and PM (both 2.5 and 10) pollution emission. As an effort to set more ambitious goals and formulate an action plan within the scope of the Atelier project, Budapest is revising the e-mobility points of its SECAP, and aims to set more ambitious goals with more concrete steps and objectives.

In a climate-neutral Budapest, majority of both renovated and new households will be powered by district heating, electricity, and renewables. 90-100% of newly constructed buildings are Nearly Zero-Energy Buildings (NZEBs) and all of the renovated or retrofitted buildings fulfil with NZEBs requirements in the climate neutral scenario. According to Budapest's SECAP goals, 100% of the old building stock will be retrofitted by 2050. Retrofitting must be done through a (nearly) zero CO_2 footprint construction with a primary reuse of existing building parts and use of recycled materials, aside of providing nearly zero energy use. Where major energy loss prevention through façade insulation is not possible (such as heritage environment), using RES and using community energy can provide to reach close to positive energy buildings as well. 20% of the city's building stock is new buildings that are using 100% electrical energy systems, and 70-80% of the building stock is made up of existing buildings that have been electrified in the climate neutral scenario. All lightning fittings are changed to LED and energy sufficient appliances, controlled by electrical appliances in smart, digital systems to reduce energy use, at the same time reduction and prevention of unnecessary electricity use will be prioritised. PVs, DH network and thermal energy are the core of the energy sources utilised within the city.

The currently active SECAP or SUMP does not cover a climate neutral transport scenario. It still needs to be elaborated. The active SECAP of Budapest that calls for a 40% reduction in emissions by 2030 compared to 2015 has a Target Má-2 which addresses transport. Its summary reads as follows:

"Má-2": Improve the energy efficiency of transport infrastructures and promote and develop environment friendly modes of transport.

The energy use of transport is responsible for about 28% of greenhouse gas emissions in the capital. Therefore, reducing GHG emissions from transport (mitigation) is the second most important overarching objective. This requires changes in all three direct elements of transport - infrastructure, vehicles and people (which cannot be rigidly separated). In general, improvements to achieve a more efficient, compact urban form, the use of local (local) facilities and services, and the use of telecommunications in travel planning can effectively reduce mobility demand. Preference is given to increasing the share of public transport, cycling and walking, encouraging the use of electric and other low or zero emission (pure electric) vehicles and micro-mobility, which can be promoted by implementing emission-reducing traffic regulations and designating climate protection zones. This will require the provision of financial support for the development of infrastructure (e.g. bicycle network, P+R and B+R parking) and the targeted renewal of public transport (including taxi services) and the municipal vehicle fleet.

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In addition, traffic management measures (e.g. entry restriction schemes, designation of low emission zones) are needed, together with public awareness and support.

The official SECAP revision with extended city vision with possible climate neutral aims for 2050 is still to be done. As a reason, the master scenario developed by Tecnalia represent the detailed city vision values for a climate neutral Budapest vision by 2050.

4.4.3. Master scenario

Budapest Master scenario represents the fulfilment of the current SECAP objectives by 2030 while it also describes the implementation of additional measures within the 2030-2050 timeframe in order to achieve carbon neutrality by 2050.

Table 15. Achieved energy savings in Budapest Master scenario.

SECTOR	2015[15] (GWh)	2030 % reduction relative to 2015	2050 % reduction relative to 2015
Residential	11.239	-44%	-59%
Private tertiary buildings	5.371	-38%	-50%
Municipal buildings	647	-30%	-43%
Street lighting	89	-23%	-37%
Industry	3.880	+33%	+9%
Agriculture	19	-72%	-72%
Municipal fleet	85	-88%	-88%
Public transport	485	-20%	-53%
Private transport	6.016	-33%	-82%
TOTAL	**27.831**	**-29%**	**-52%**

In line with the Hungarian National Clean Development Strategy[16], the decarbonisation of the national power grid has been considered by 2050. Hence, thanks to the electrification of the end-use sectors, the decarbonisation of the city DH network (see section 0), and the penetration of other technologies (H_2 in transport and industry, solar PV in buildings, and other renewables in buildings), carbon neutrality is achieved in the city by 2050.

Table 16. Achieved GHG[17] savings in Budapest Master scenario.

SECTOR	2015 (kton CO2)	2030 % reduction relative to 2015	2050 % reduction relative to 2015
Residential	2.268	-52%	-100%
Private tertiary buildings	1.165	-60%	-100%
Municipal buildings	139	-58%	-100%
Street lighting	21	-54%	-100%

[15] As new data has been available, energy and emissions data for the years 2015 and 2019 has been updated with regard the BaU version in D2.5.

[16] https://unfccc.int/sites/default/files/resource/LTS_1_Hungary_2021_EN.pdf

[17] Note that GHG emissions in all figures and tables for the Budapest Master scenario reflect a scope 2 assessment. That is, power and heat generation emissions are allocated to the final energy consumption of electricity and heat in end-use sectors.

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Industry	809	-8%	-100%
Agriculture	5	-82%	-100%
Municipal fleet	11	-76%	-100%
Public transport	123	-22%	-100%
Private transport	1.571	-34%	-100%
TOTAL	**6.112**	**-40%**	**-100%**

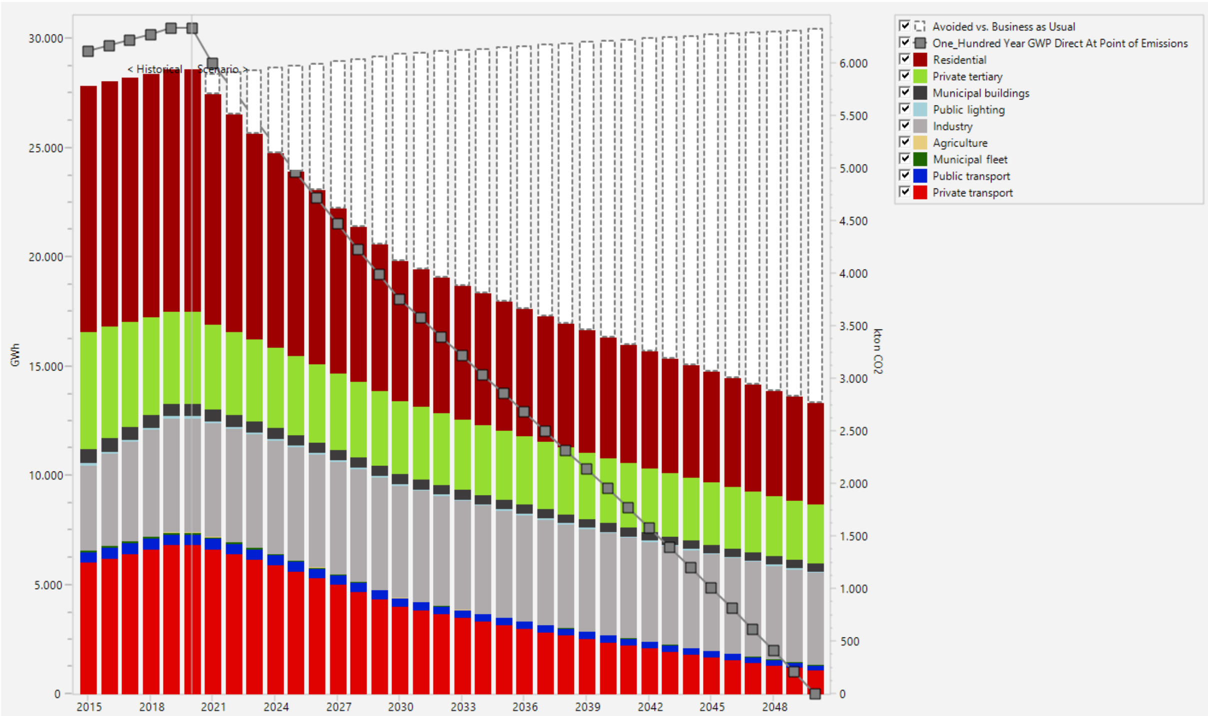

Figure 24. Budapest energy consumption and GHG emissions by sector in the Master scenario.

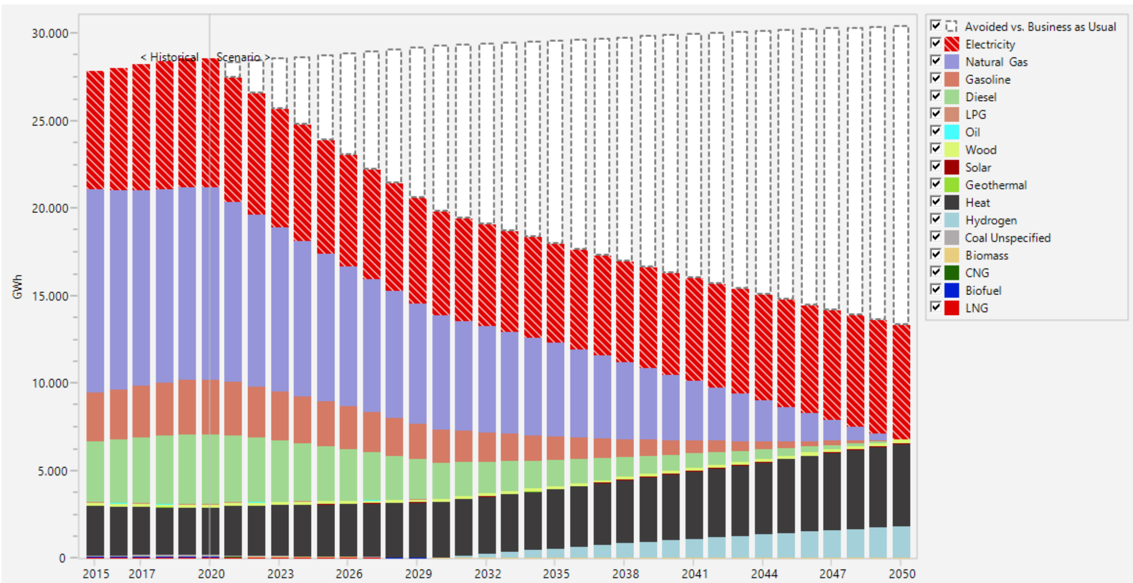

Figure 25. Budapest energy consumption by fuel in the Master scenario.

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Next sections describe the assumptions and specific sectoral results of the Budapest Master scenario.

Residential buildings

According to the current city SECAP, 1/3 of the city's household is renovated (including envelope and heating systems renovation) by 2030. The renovation of the whole household stock is fulfilled by 2050. Regarding achieved savings by the renovation of households, a 60% energy reduction with regard existing buildings has been considered for a full household renovation (including envelope renovation and substitution of heating systems), while new households are assumed to use 90% less energy than existing ones. Moreover, it has been considered that existing households that do not renovate their envelope, substitute their old and inefficient heating systems, achieving an energy efficiency improvement of 35%.

Table 17. Energy intensity (in MWh/household) by household type in Budapest Master scenario.

	2015	2030	2050
Existing households	12,35	7,82	7,82
Renovated households	-	4,94	4,94
New households	-	1,25	1,25

Along with the energy savings reached by the renovation of households (including envelope renovation and substitution of heating systems), the fuel mix 61ft he sector is modified accordingly, achieving the full decarbonisation 61ft he sector thanks to a combination of heat electrification, DH decarbonisation and renewables penetration.

Table 18. Fuel mix by household type in Budapest Master scenario.

<table>
<tr><th></th><th></th><th>2015</th><th>2030</th><th>2050</th></tr>
<tr><td rowspan="5">Existing households</td><td>Electricity</td><td>18,07%</td><td colspan="2">20%</td></tr>
<tr><td>DH</td><td>19,35%</td><td colspan="2">22,95%</td></tr>
<tr><td>Natural gas</td><td>60,33%</td><td colspan="2">55%</td></tr>
<tr><td>Other fossil fuels</td><td>0,78%</td><td colspan="2">0%</td></tr>
<tr><td>Renewables (biomass & solar thermal)</td><td>1,47%</td><td colspan="2">2,05%</td></tr>
<tr><td rowspan="5">Renovated households</td><td>Electricity</td><td>-</td><td>20%</td><td>50%</td></tr>
<tr><td>DH</td><td>-</td><td>25%</td><td>45%</td></tr>
<tr><td>Natural gas</td><td>-</td><td>50%</td><td>0%</td></tr>
<tr><td>Other fossil fuels</td><td>-</td><td>0%</td><td>0%</td></tr>
<tr><td>Renewables (biomass & solar thermal)</td><td>-</td><td>5%</td><td>5%</td></tr>
<tr><td rowspan="5">New households</td><td>Electricity</td><td>-</td><td colspan="2">50%</td></tr>
<tr><td>DH</td><td>-</td><td colspan="2">45%</td></tr>
<tr><td>Natural gas</td><td>-</td><td colspan="2">0%</td></tr>
<tr><td>Other fossil fuels</td><td>-</td><td colspan="2">0%</td></tr>
<tr><td>Renewables (biomass & solar thermal)</td><td>-</td><td colspan="2">5%</td></tr>
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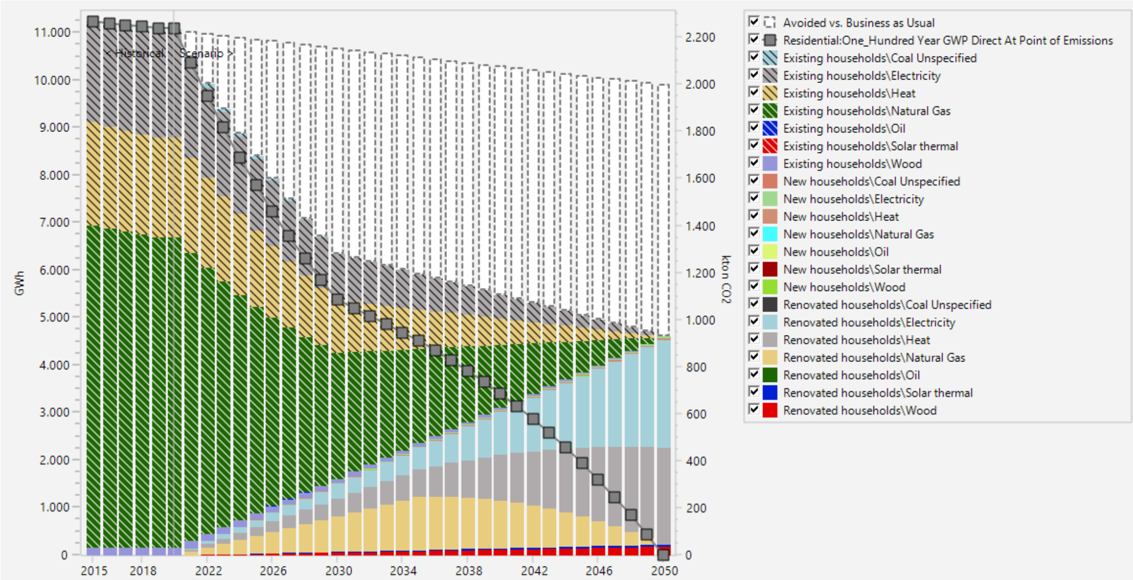

Figure 26. Residential energy consumption (by type of households and fuel) and GHG emissions in Budapest Master scenario.

Private tertiary buildings

The observed and modelled historical trend in the BaU scenario already represents a significant reduction of energy use in the sector implying that energy efficiency measures are already being undertaken. This evolution is already aligned with the current SECAP 2030 medium-term goals and with the city long-term decarbonsiation targets. Therefore, no additional energy efficiency measures have been assumed in the Master scenario, not achieving further reductions relative to the BaU scenario. The progressive substitution of natural gas by heat from DH has been considered, thus achieving the full decarbonisation of the sector (since heat and electricity networks within the city are carbon-free by 2050).

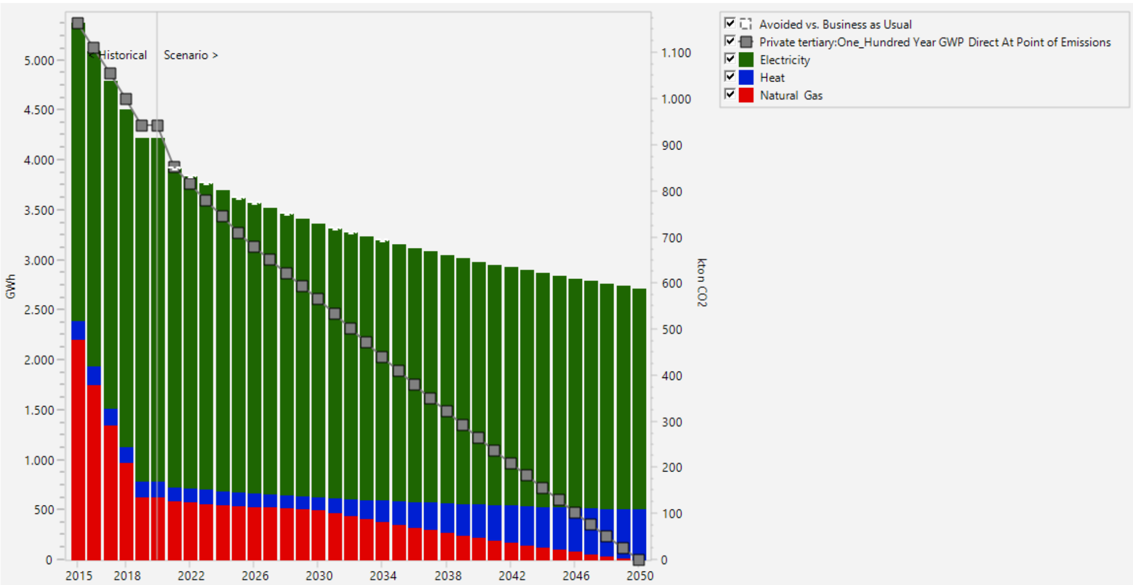

Figure 27. Private tertiary buildings energy consumption and GHG emissions in Budapest Master scenario.

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Municipal buildings

As for private tertiary buildings, the observed and modelled historical trend in the BaU scenario for municipal buildings already represents a significant reduction of energy use in the sector implying that energy efficiency measures are already being undertaken. Indeed, SECAP 2030 objectives for these buildings are already met in the BaU scenario. Therefore, no additional energy efficiency measures have been assumed in the Master scenario, not achieving further reductions with regard the BaU scenario. Concerning fuel switching assumptions, liquid fossil fuels (gasoline, heating oil, LPG…) are phased out by 2030, while natural gas is subsequently removed from 2030 to 2050. These fuels are replaced by biomass systems and mostly by heat from DH. Solar thermal systems are also contemplated but to a lesser extent, as well as a slight electrification of heat demand, fulfiling the decarbonisation of the sector.

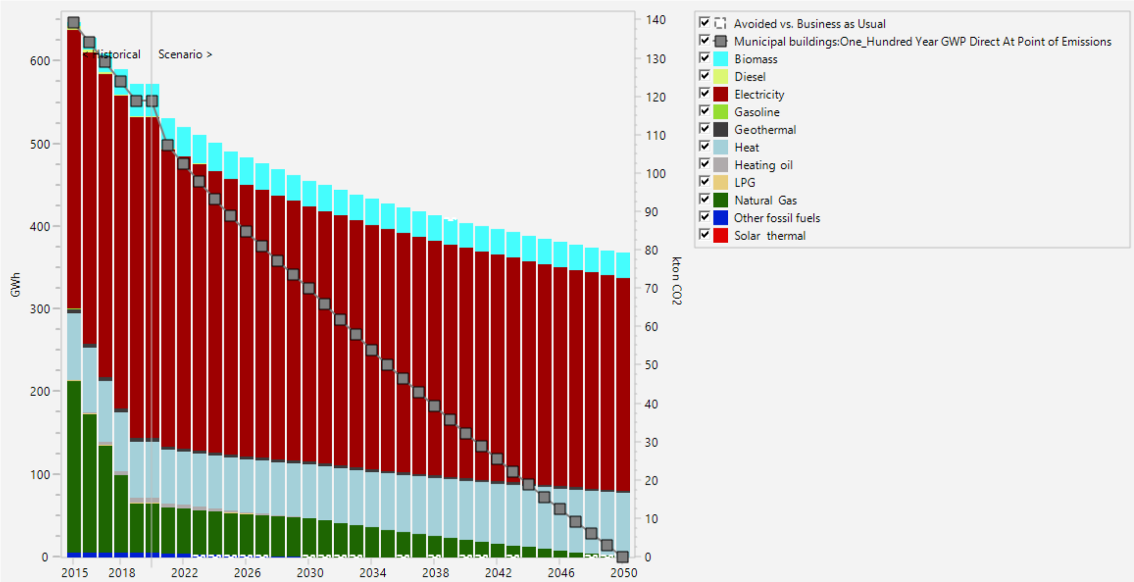

Figure 28. Municipal buildings energy consumption and GHG emissions in Budapest Master scenario.

Street lighting

Regarding street lighting, it is assumed that by 2030 almost 60% of post lamps are LED technology, reaching a 100% LED stock by 2050.

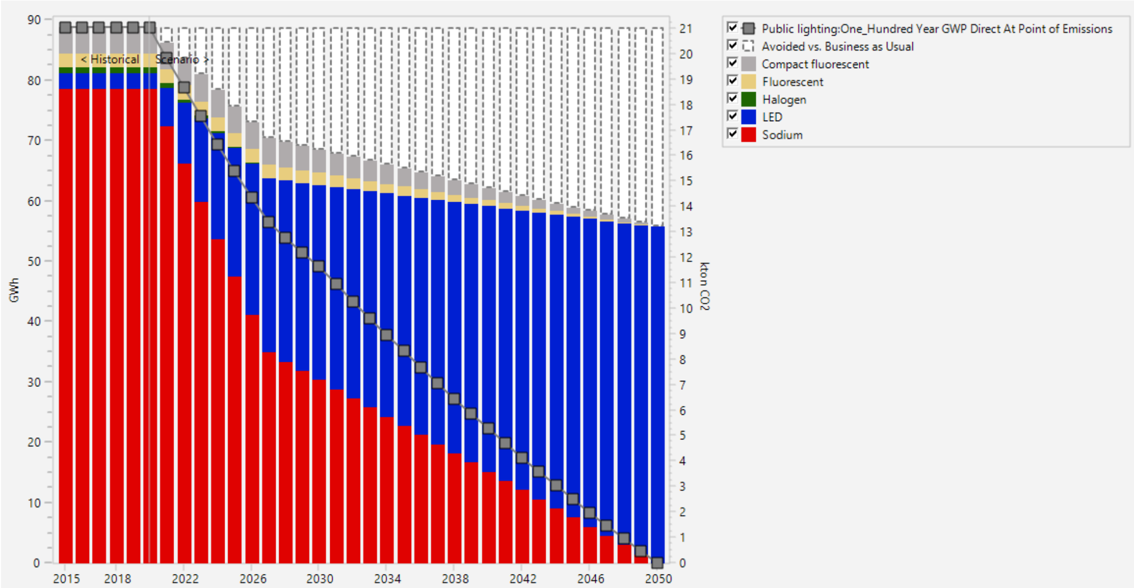

Figure 29. Street lighting energy consumption and GHG emissions in Budapest Master scenario.

Industry

Thanks to energy efficiency measures, the industry sector reduces its energy use: by 2030 the energy reduction target set by the city SECAP is reached, while a 1% yearly reduction in energy consumption is considered from 2030 to 2050. Moreover, it is assumed that natural gas is progressively replaced by heat from DH and hydrogen (since 2030) reaching the full decarbonisation of the sector by 2050.

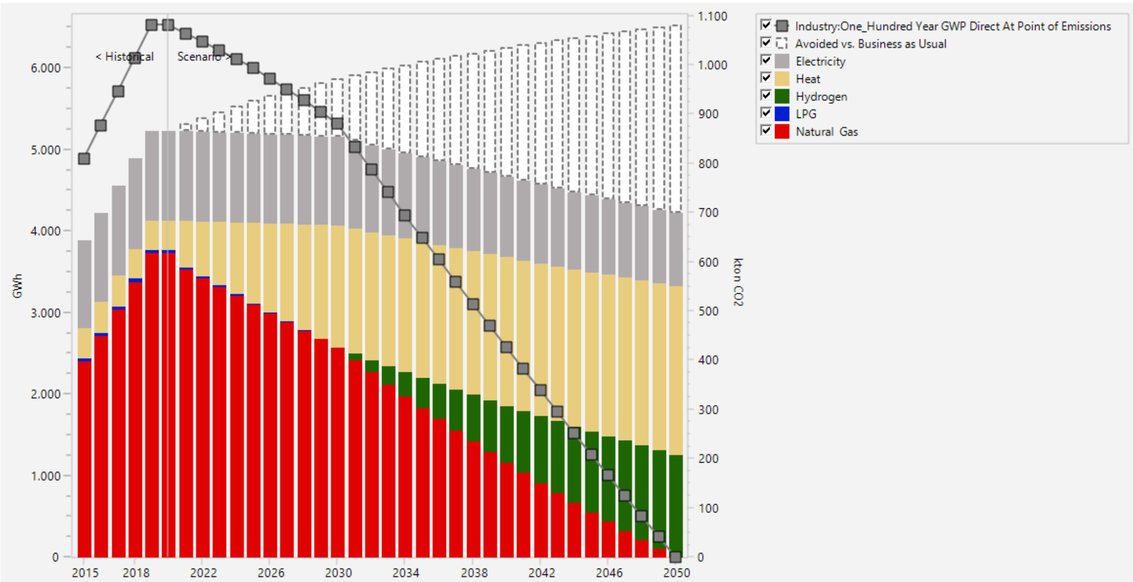

Figure 30. Industry energy consumption and GHG emissions in Budapest Master scenario.

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Agriculture

No changes with regard the BaU scenario have been considered in the agriculture sector.

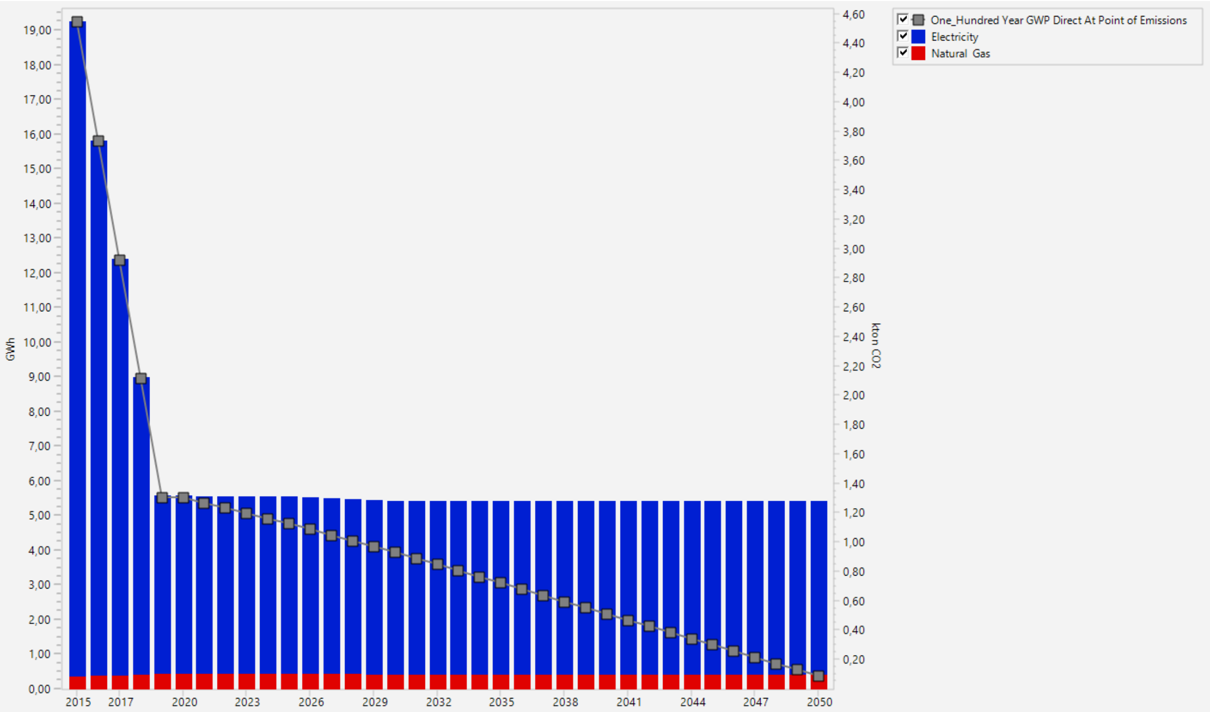

Figure 31. Agriculture energy consumption and GHG emissions in Budapest Master scenario.

Municipal fleet

All municipal fleet vehicles are assumed to be electrified by 2030.

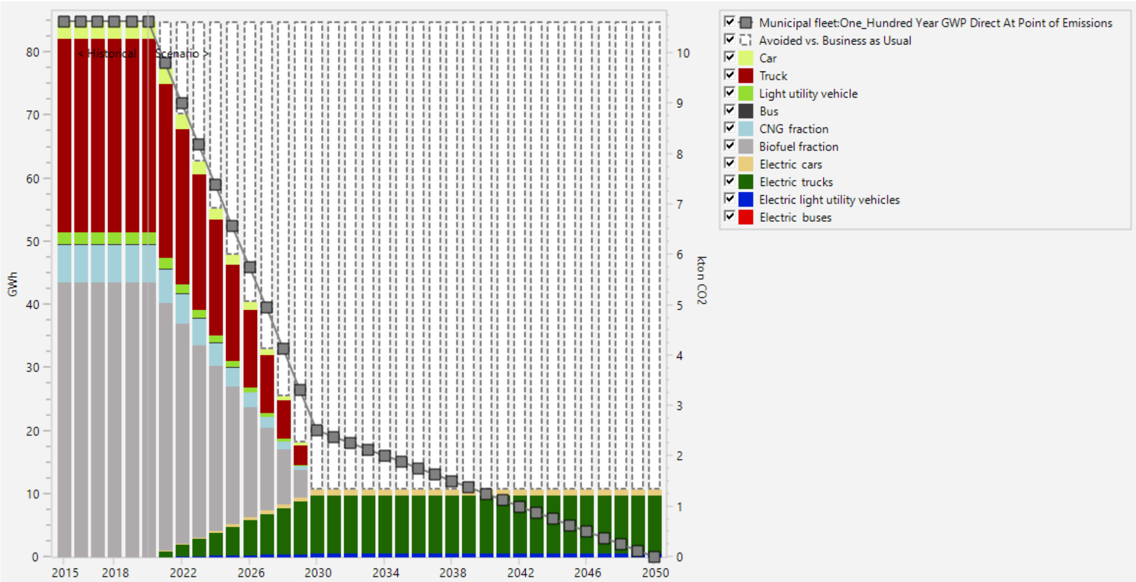

Figure 32. Municipal fleet energy consumption and GHG emissions in Budapest Master scenario.

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Public transport

On the one hand, activity of metro, tramway, and trolley buses is assumed to remain unchanged. On the other hand, the number of buses is assumed to be increased by 5% (2030) and 10% (2050), assuming a shift from private transport towards this public transport mode. Concerning the bus stock mix, it has been considered that 30% of the bus fleet is electrified by 2030, while 4% of buses use natural gas as fuel. Remaining buses (66%) are still diesel (hybrid) by this year. The whole bus fleet is electrified in 2050.

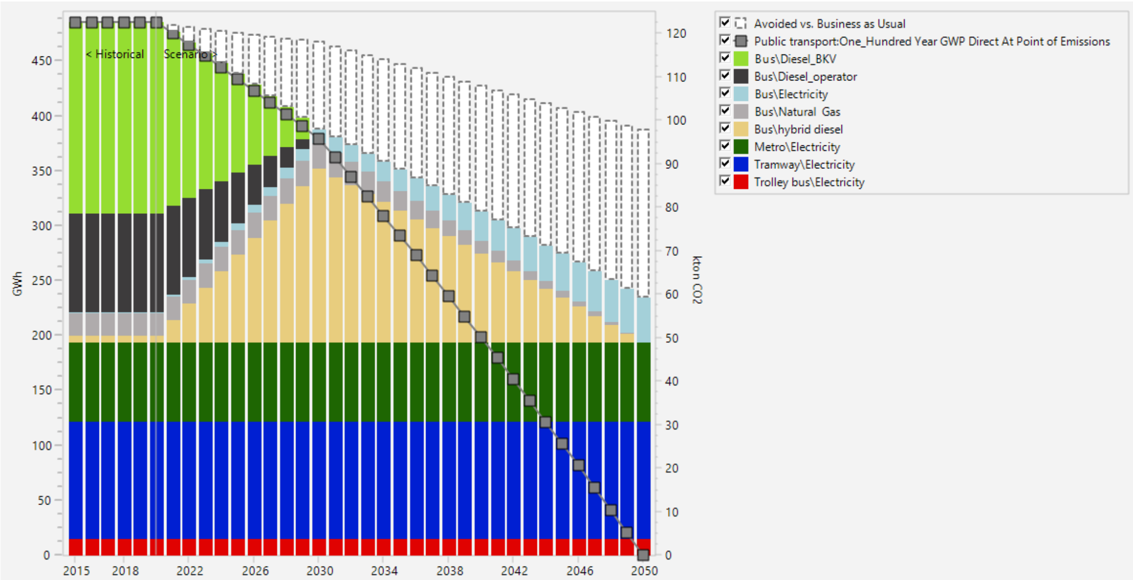

Figure 33. Public transport energy consumption and GHG emissions in Budapest Master scenario.

Private transport

Use of private passenger (cars, motorcycles, buses) and freight (trucks) vehicles is assumed to decrease. In that sense, a reduction in both the number of vehicles that travel within the city, as well as in the mileage of fossil fuelled vehicles has been considered. For the latter, this mileage reduction in diesel and gasoline vehicles represents the result of the implementation of low-emission zones, other restrictions to the most pollutant vehicles, and the use of other means of transport.

Table 19. Private vehicle fleet stock evolution in Budapest Master scenario.

	2015	2019	2030[18]	2050
Cars	597.189	684.197	597.189	537.470
Motorcycles	24.906	27.862	24.906	24.906
Trucks	80.906	98.435	76.861	64.725
Buses	2.568	3.113	2.568	2.311

[18] It is assumed that by 2030, the number of vehicles reaches the same value as the base year (2015).

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Table 20. Private vehicle fleet mileage reduction (only in fossil fuelled vehicles) in Budapest Master scenario.

	2030 (relative to 2015 mileage)	2050 (relative to 2015 mileage)
Cars (diesel and gasoline)	-20%	-30%
Trucks (diesel)	-30%	-40%

In addition to the reduction of the private vehicle fleet stock and travelled mileages, a switch between fuels used by the different vehicles has been considered.

Table 21. Fuel mix evolution by vehicle type in Budapest Master scenario.

		2015	2030	2050
Cars	Diesel	40%	30%	0%
	Gasoline	60%	50%	0%
	Electricity	0%	20%	70%
	Hydrogen	0%	0%	30%
Motorcycles	Gasoline	100%	70%	0%
	Electricity	0%	30%	100%
Trucks	Diesel	100%	90%	0%
	Electricity	0%	10%	40%
	Hydrogen	0%	0%	60%
Buses	Diesel	96%	86%	0%
	Electricity	0%	11%	70%
	LNG	4%	3%	0%
	Hydrogen	0%	0%	30%

Energy consumption related to private transport use is therefore reduced thanks to the implementation of mobility measures such as traffic restrictions or public transport fostering (modelled through the reduction of vehicle stocks and mileages) and the efficiency improvement associated to the new powertrains (i.e. electric, hydrogen, hybrids…). Accordingly, GHG emissions related to the sector are reduced until a decarbonised mobility is achieved by 2050.

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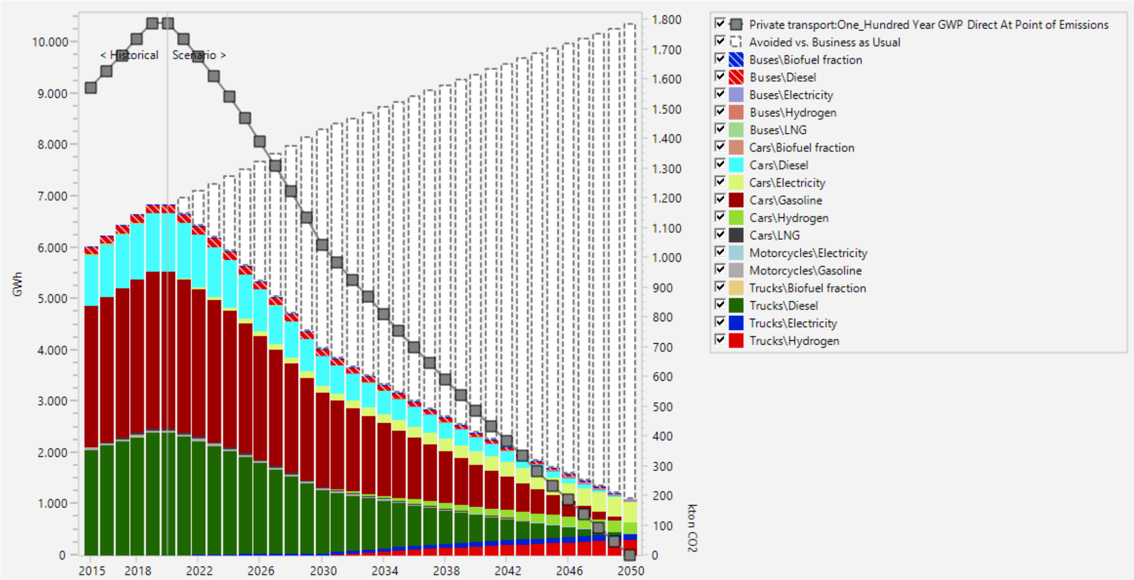

Figure 34. Private transport energy consumption (by type of vehicle and fuel) and GHG emissions in Budapest Master scenario.

Local energy production

As indicated in the SECAP document, 1500 MW of solar PV panels can be potentially installed by 2030 in the city. Concerning the 2050 time horizon, the 2020-2030 linear trend has been extrapolated to the future, reaching a total installed capacity of 4500 MW by 2050.[19]

[19] It should be borne in mind that the 2030-2050 projection does not account for the technical/physical feasibility of these installations (i.e. available surface, irradiation, shading issues…). Hence a more thorough analysis should be carried out to obtain a more coherent and accurate estimation.

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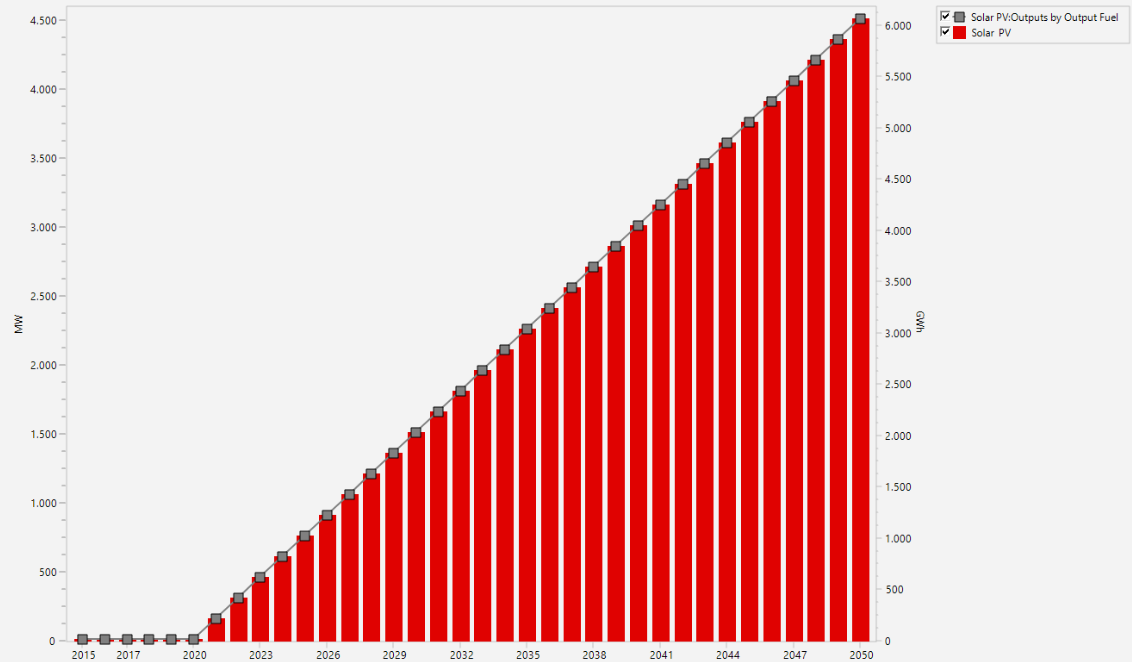

Figure 35. Solar PV installed capacity (bars) and electricity generation (dotted line) in Budapest Master scenario.

In order to decarbonise local energy generation, it has been assumed that renewable sources (geothermal, biomass, municipal solid waste) are progressively used in heat only boilers and CHP plants. Thus, 50% of the heat and electricity produced within the city come from renewable sources by 2030, reaching 100% by 2050. No more capacity is assumed to be installed in heat only boilers and CHP plants. Altogether, all the heat and electricity consumed within the city is produced within its borders.

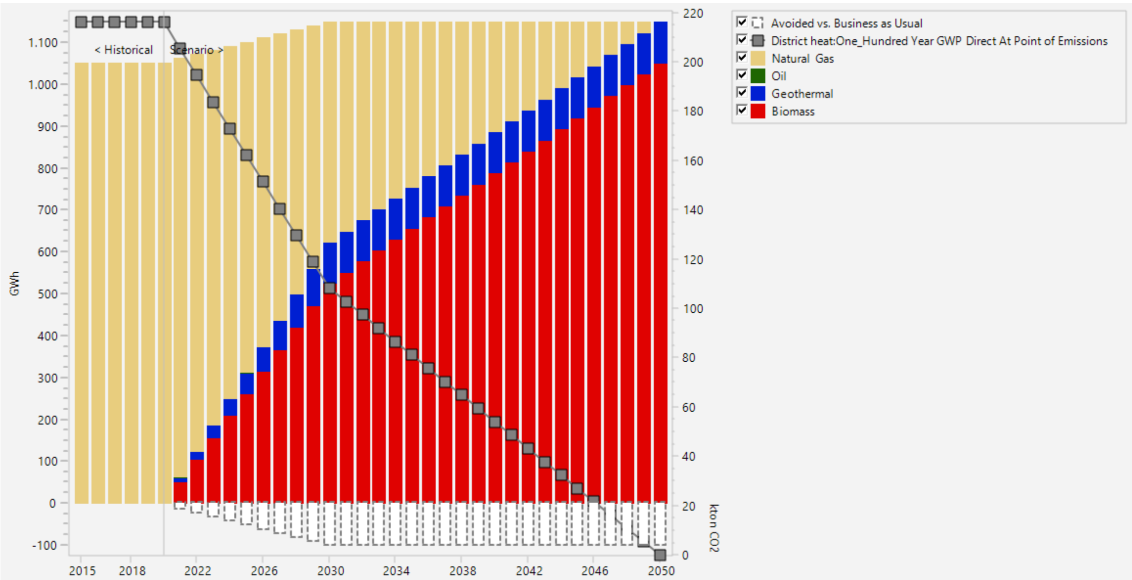

Figure 36. Heat produced by source in heat only boilers plants in Budapest Master scenario.

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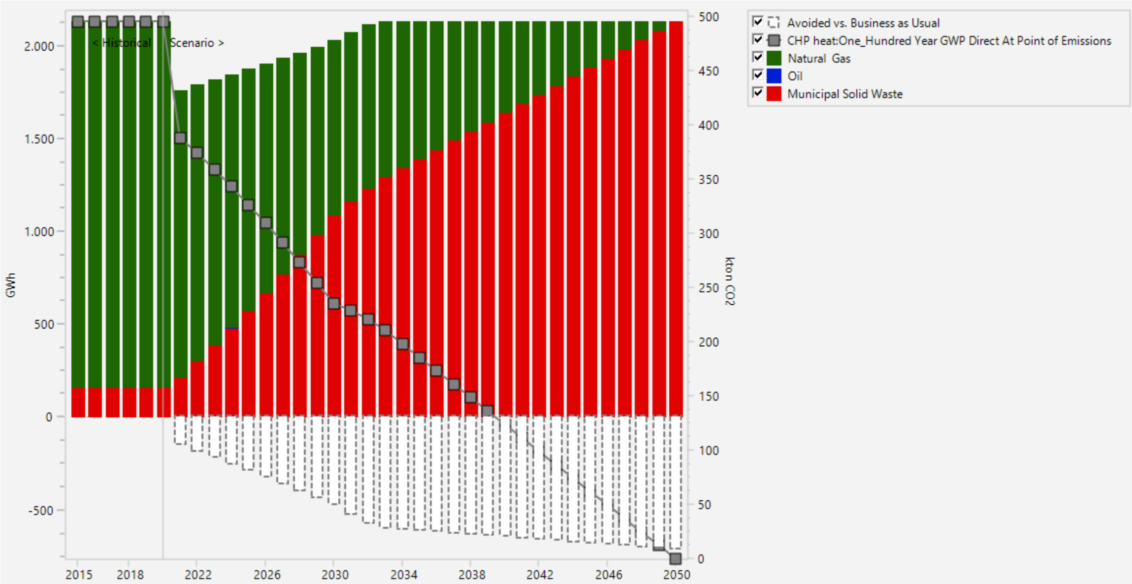

Figure 37. Heat produced by source in CHP plants in Budapest Master scenario.

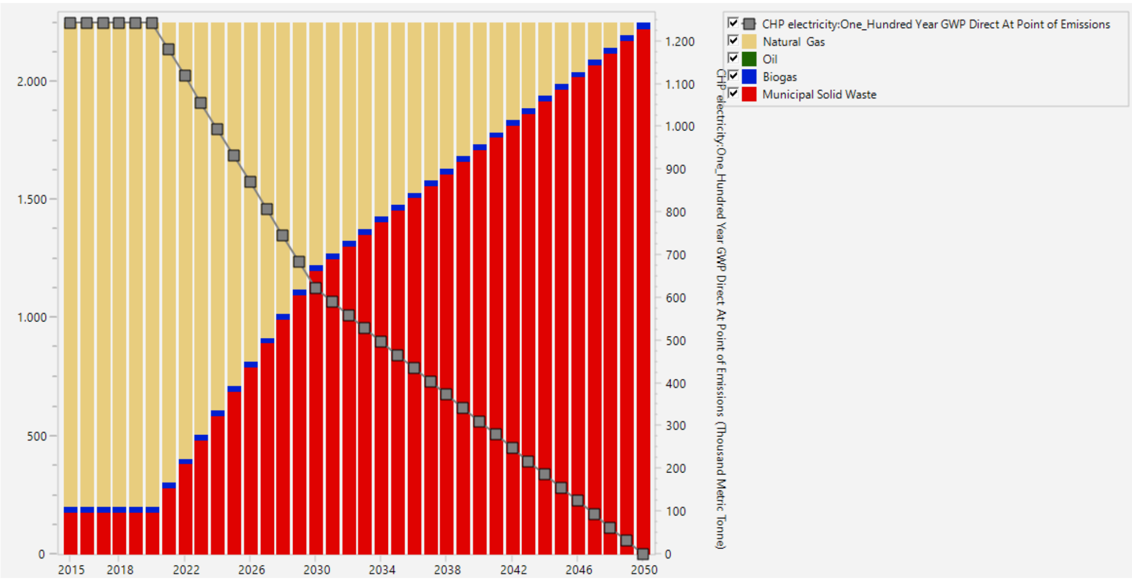

Figure 38. Electricity produced by source in CHP plants in Budapest Master scenario.

4.4.4. The role of PED in City Vision

City of Budapest is one of the cities in the "100 Climate-Neutral and Smart European cities" mission initiative. This initiative aims at accelerating the energy transition by supporting 100 cities to achieve climate neutrality already by 2030.

PEDs play a crucial role in the City Vision to accomplish an accelerated urban energy transition and decarbonisation of the city on smaller neighbourhood level. As for urban territories in EU, buildings account for 40% of the total energy consumption [Directive 2010/31/EU], however, annually, only 1.3% of the residential building stock is undergoing a medium-to-deep energy

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retrofit. Energy efficiency refurbishment of the existing building stock and a green energy transition must be accelerated to utilise renewable energy sources in the neighbourhoods, locally. At the same time, new urban developments are ought to follow PED principles, too, in order to prevent the appearance of new neighbourhoods which do not have a positive energy balance. A wide spread of PED transition throughout the city can offer small scale neighbourhood-level solution to reach climate neutrality through improving energy efficiency, integrating renewable energy, improving energy resiliency and reliability, supporting environmental sustainability, providing economic benefits and a better quality of life to its community through innovation and technology, prioritising mixed land-use, sustainable transportation in the neighbourhood and forming a local community engagement. PED formation requires important regulatory and policy framework changes which will catalyse further sustainable development.

The PED scenario studied within the ATELIER project for Fehérdűlő area relies on a mixed-use development to leverage collective and inclusive interconnected energy network solution, involving all members of the community, in order to provide affordable renewable energy to the members and even produce possibly an energy surplus that can be made available for the surrounding neighbourhood, contributing to the achievement of Budapest's climate goals by 2030.

Thanks to the PED concept development study for Fehérdűlő and the connected workshops with local experts Budapest learned how to develop a Positive Energy District in the city and to learn what are the key constrains and barriers that needs to be overcome in order to achieve and implement a PED in practice. The key findings are the following:

- Currently, there are national regulatory limitations for creating energy communities, as the main barriers for true utilisation of PEDs
- It is important to make the banking sector interested in financing PEDs and also initiating investment platforms to bring additional benefits and enable the investment to become more feasible
- In addition to legal and economic support, it is necessary to create an Energy Use Strategy or Action Plan
- Storing energy and supplying energy excess can be one of the main technical issue of PED creation
- The need to establish an Energy Management organization was articulated
- It is necessary to define exactly what we mean by energy community, what are the exact roles, and create a new business model to run an EC

Some further realisations have been acknowledged as well:

- Local governments must take the initiating role
- The local district authorities could take a role in the designation of possible areas
- Involvement of local SMEs into the PEDs can become a priority aspect
- Importance of community civil platform creation
- Informing and educating users is essential
- There is a need for community obligation related to EC in PED creation
- PED should be an OPEN system

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4.5. Copenhagen

Copenhagen Climate Plan 2012-2025 has as ambition that Copenhagen becomes carbon neutral by 2025. Specific targets include reduction of energy consumption (20% reduction in heat consumption, 20% reduction in power consumption in commercial and service companies, 10% reduction in power consumption in households), increasing energy production based on wind and biomass, increasing green mobility (75% of all journeys takes place on foot, by bicycle or by public transport), and 40% reduction of energy consumption in city administration buildings.

Given the significant progress Copenhagen has already made in the pursuit of a green energy transition, the "remaining" climate mitigation challenges facing Copenhagen are not easily overcome. In our thoroughly regulated society with well-established institutions that are used to optimizing their businesses, we have to innovate and integrate the different sectors of society in new and more radical ways.

Furthermore, we are globally facing a fast-approaching climate crisis. What is facing us is so-called "wicked problems" or even "super-wicked problems" (see for example 'Super Wicked Problems and Climate Change: Restraining the Present to Liberate the Future', Richard J. Lazarus, 2009)

These problems are characterised by the fact that:

- Time available for solving them is running out.
- Those who try to solve the problems are also part in creating the problems.
- The government cannot control the societal choices that must be made in order to find a solution.
- Decision-makers are more worried about the short-term costs than the long-term consequences.

What is needed is not to tame the problems or solve them but rather to develop a common understanding of the problems and a common understanding of possible solutions – the target being not find the one and only solution but to create a focused and cohesive effort since it is impossible to solve the problems in a way that is simple and final. What is required is a holistic approach to future focused solutions. And this is best done through collaborative reasoning in involving all parties so that a multitude of resources are mobilised, and a joint ownership of the solutions is formed.

These two points form the background for the choice of process for the vision development of Copenhagen for the period 2026-2035 and forward to 2050.

4.5.1. Process followed for city vision development

The Copenhagen City Council decided in 2021 on three overall guide marks for the climate efforts – see figure below. What these guide marks will actually signify, has not yet been finally decided by the politicians. Currently a baseline is being developed against which the guide marks can be discussed and defined. The City Council is expected to make a decision in December 2023 regarding the interpretation of the guide marks.

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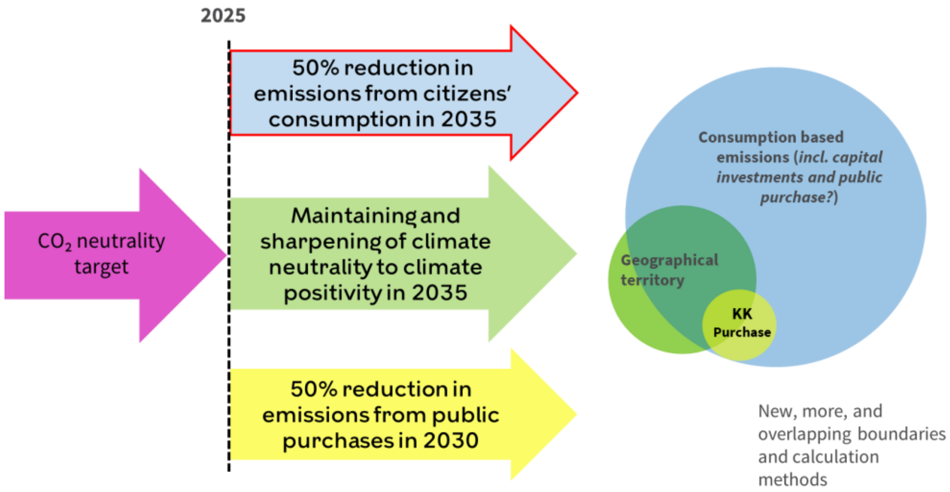

Figure 39. Politically agreed guide marks of Copenhagen City Council.

The Copenhagen Climate plan 2035 (traditional and new topics) will be developed in a continuous consultation process aimed to last up to two years, and will address all the Cities4Zero process steps Engage, Analyse, Diagnose, Envision, Plan but in a more iterative manner. Currently, Copenhagen is at the Engage, Analyse, and Diagnose steps.

The city vision development process has been divided into two phases – A prior loosely explorative phase and then the main development phase. In the first phase, professionals were on a number of occasions invited to discuss energy challenges while the second phase marks the actual collaborative work of developing the Climate Plan 2035.

Phase 1 - Initial exploration with professionals	Phase 2 - Climate Plan development with all of the city
•14feb2020 - Annual climate conference of CPH City •03may2022 - Kick-off seminar •24apr2023 - Images of the future workshop	•Mayors' Forum •Directors' Forum •.. •Energy Strategic Forum •...

Figure 40. Vision development started with "loose" explorative discussions (phase 1) followed by a more formal development process (phase 2).

<u>Phase 1</u>

Already on 14 February 2020, the annual climate conference of Copenhagen City not only gave a status on the progress of achieving the targets set in Climate Plan 2012-2025 but also aimed to provide specific input to the Climate Roadmap 2021-2025 under preparation and the upcoming Climate Plan 2035/2050 which sets the framework for what needs to happen after 2025 in order for Copenhagen to meet its climate targets.

The following COVID crisis led to a temporary halt in the process relating to the next Climate Plan. The work was re-launched with a **kick-off seminar on 03 may 2022 for the Climate**

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Plan 2035. The seminar was aimed at professionals within not only the energy sector but also areas relating to consumption of resources and was presided by the Mayor of Technique and Environment. The role of the seminar was to initiate the work, to come to a joint understanding of the challenges, potentials, and attractive targets within the different topics, and to engage and involve key professional stakeholders in the upcoming work (see Danish news article at https://tmf.kkintra.kk.dk/indhold/arbejdet-med-den-nye-klimaplan-er-i-gang).

The seminar was organised in seven parallel tracks as well as plenary sessions. The topical tracks were: 1) The energy system of the future with a focus on **energy planning**; 2) The energy system of the future with a focus on **energy strategy and new technology**; 3) Energy **consumption** in **buildings** – How do we get energy efficient operation and service of buildings to the next level?; 4) How do we want to live and build in the future – **Energy refurbishment**, sustainability, and "the new city"; 5) Local and **citizens-close energy solutions** – Decentral energy solutions, flexible energy consumption, and energy communities; 6) **Green mobility** in a living city; and 7) Transition to **zero emission vehicles**. Each track was asked to deliver a set of conclusions after a day of presentations and discussion – What are the main challenges that we face? What could the ambition and targets look like? What analyses do we need to initiate to obtain missing information/data? What are the three next steps in our work process?

More than 120 professionals participated. One of the findings from the energy related discussions was that the technical solutions can be found but the required organisational change and a lack of manpower will constitute significant challenges.

In February 2023, a total of 61 selected professional stakeholders were invited to a series of moderated workshops and given the task to formulate a set of energy related "**Images of the Future**". Three external experts were asked to deliver the necessary factual input.

The Images of the Future are suggestions for how an attractive future with regards to energy, heating, building and mobility in Copenhagen might look under the assumption that Copenhagen aims for climate positivity and energy flexibility. The focus is solely on energy related matters (and not general resource consumption). The images are not databased, modelled scenarios but rather professional assessments.

They arrived at 4 images and five fundamental dilemmas for the green transition in Copenhagen. The images are: 1) A capital based on green electricity, 2) Sustainable heating for all; 3) Energy efficient buildings; and 4) Mobility without emissions. The fundamental dilemmas that the green energy transition faces are according to the consulted professionals:

- Electricity will play a main role in achieving a larger share of renewable energy within all sectors of the economy but at the same time this increased electricity demand will put pressure on the electricity grid and our security of supply.
- It is difficult to unite a full phase out of biomass with a stable and secure supply, and if our aim is climate positivity (i.e. removing more CO_2 than is emitted) this will require that we have combustion plants for carbon capture.
- Converting to electric mobility might take up a significant amount of the city space. However, electric mobility can have the added benefit of e.g. reduced environmental pollution.
- The good city life has been equal to increasing living space and functions within the individual household. Choosing sustainability will require that we reduce living space per person and find new ways to accommodation and living.

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- We are facing decisions that will shape our city and way of life for the long term, but we have a brief window of time to make those long-term decisions. And we have to make decisions in a situation where the technological, political, social, and economic conditions are rapidly changing.

Phase 2

The organisational set-up of the second phase of the Climate Plan Vision development is quite complex, as can be seen in the figure below. The Climate Secretariat under the Technical and Environmental Administration (TMF) acts as project manager and facilitates the work processes. The City Council has commissioned the Climate Plan and agreed the three guide marks for the Climate Plan 2035. Cross municipal work groups containing also external stakeholders carry out the work and report to the Board of directors. Key administrations in the work are the Technical and Environmental Administration (TMF) and the Financial Administration (ØKF).

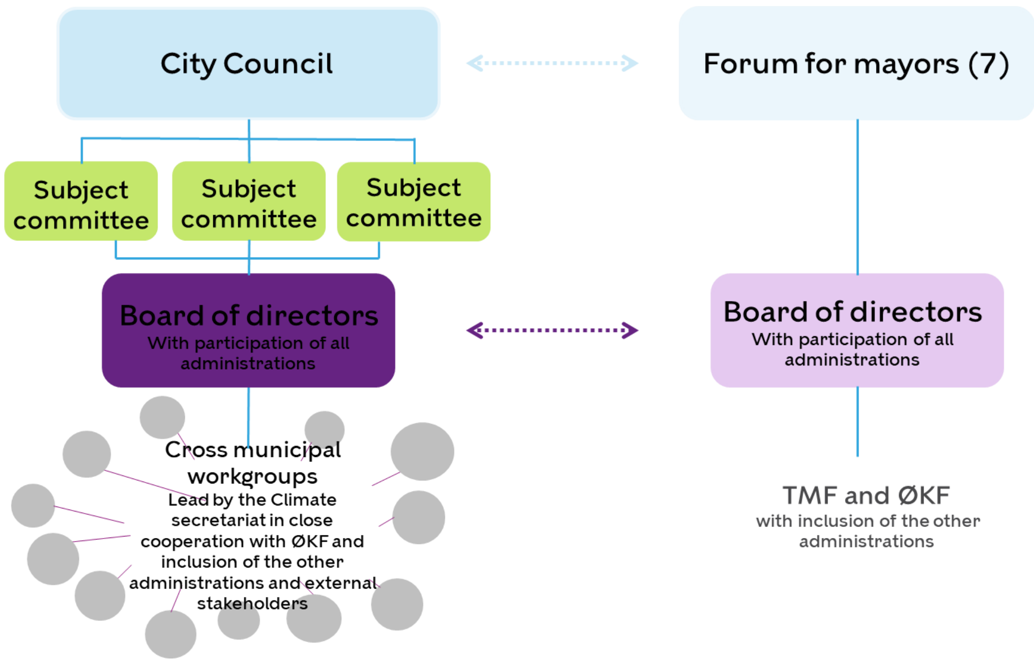

Figure 41. Organisation of Copenhagen's Climate plan 2035 work. (Note: Copenhagen has seven mayors – one Lord Mayor and six subject specific mayors and they may represent different political parties).

On April 24 2023 a full day Climate Plan Seminar for municipal employees from all city administrative areas of expertise kick-started the internal networking and brainstorming on how the municipal administration impacts the climate and how we can contribute to the transformation. More than 100 employees participated, and 10 cross municipal workgroups were formed each with their separate core topic. The topics included climate education, energy strategy, green competences, mobility, construction, travel & experiences, physical planning, food, consumables, and public purchase. https://tmf.kkintra.kk.dk/indhold/100-klimakloge-kolleger-sk%C3%B8d-ny-klimaplan-i-gang

Each work group is headed by a representative from the Climate Secretariat who also assists in facilitation. The group consists of a smaller or larger number of cross city administration representatives and selected external stakeholders.

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The work group for Energy Strategy 2035 consists of several smaller sub-groups. These sub-groups submit their work to an Energy Strategic Forum consisting of leaders of the key energy stakeholders – HOFOR (district heating company), Cerius-Radius (electricity network operator), CTR (heat production, Ørsted (heat and power production), ARC (waste incineration), and Energinet (electricity transmission system operator) as well as the Technical and Environmental Administration (TMF) and the Financial Administration (ØKF).

The Energy Strategy will show the direction for the development of the energy system in Copenhagen at least 10 years into the future and indicate perspectives for the period until 2050. The Energy Strategy will provide the strategic base principles for how we together pro-actively and in an agile manner can ensure a holistic development of the energy system for the common good and how to prioritise between the different interests and dilemmas which Copenhagen expects to face. The principles will thus guide the development of specific initiatives and investments that will be prioritised over the next 10 years. The subgroups are shown below.

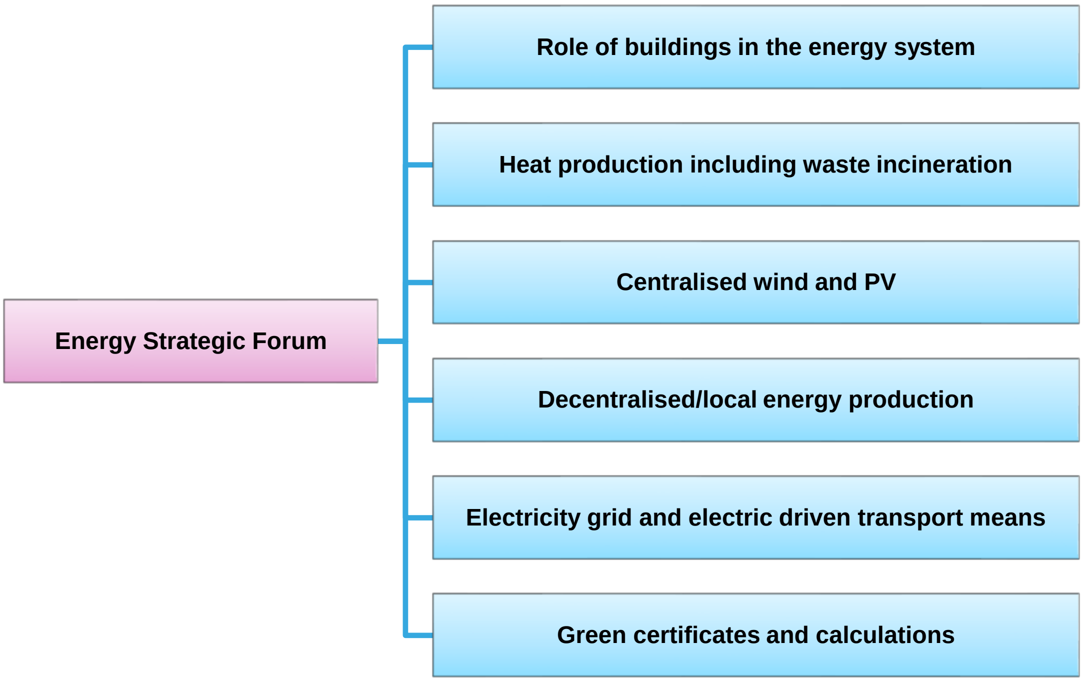

Figure 42. The energy strategy work is organised in six subgroups reporting to an Energy Strategic Forum.

The task of the energy strategy sub-groups is to describe their topic and the associated dilemmas, as well as assess the need for additional data and analyses (and association required budget). Next the subgroups will develop a vision for their topic and identify which key elements determine which way the development will go and identify initiatives that will help achieve the new climate targets of Copenhagen. First delivery to the Energy Strategic Forum is due January 2024.

It is expected that the Energy Strategy 2035 will be submitted to the City Council for approval in May 2024. Input may also be provided from the Citizens Climate Assembly and local Climate Summits charged with providing input for the entire Climate Plan.

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The development of a gross list of climate initiatives for the action plan will be developed in the course of the first half of 2024. Specific targets and sub-target are decided in May 2024 together with selecting initiatives to be launched. Overall, the Climate Plan 2035 is expected complete and adopted by the City Council by the end of 2025 after a public hearing.

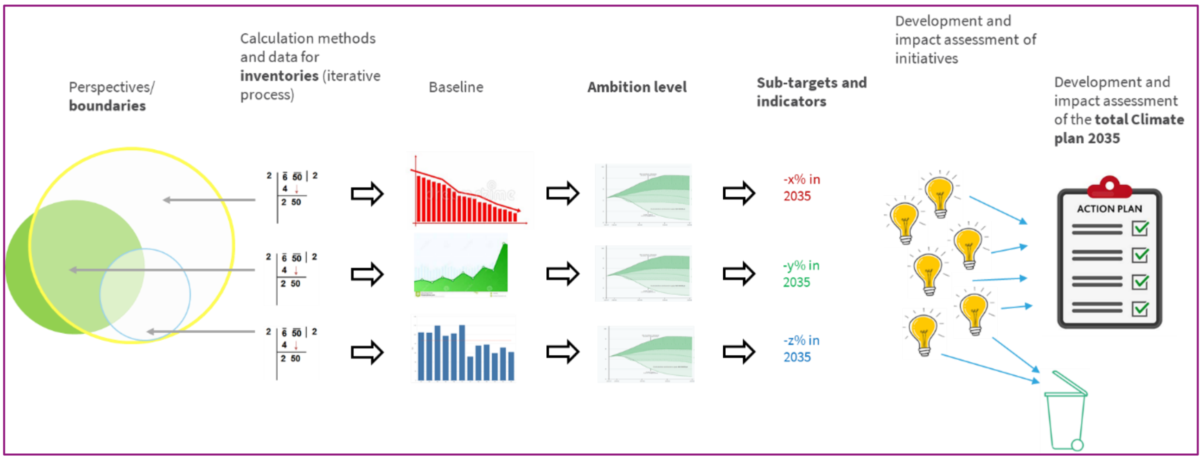

Figure 43. Visual representation of the stepwise tasks for development of Copenhagen's Climate Plan 2035.

4.5.2. City Vision

The expectation is that Copenhagen will set as target to become climate positive in 2035. What exactly this entails, is yet to be decided.

Although the upcoming climate plan is named Climate Plan 2035 it will contain a vision towards 2050. The radical changes that our energy system and society have to undergo in order to become more sustainable cannot be achieved overnight.

More information will be available during 2024.

4.5.3. The role of PED in City Vision

Copenhagen has almost full coverage by district heating and the district heating is supplied by a company partly owned by the municipality. The common understanding is that any attempts at achieving an affordable heat supply for all, that is also sustainable, will involve district heating and improving buildings and changing the role that buildings play in the energy system. The discussion on PED is helping to push the boundaries for what can be done. The Danish heat sector is thoroughly regulated and updating the regulation is critical for achieving sustainability goals. Until recently, district heat companies were not allowed to own or operate consumer installations – their only mandate was to provide a certain temperature and flow of supply "to-the-door". Discussions on individual and local heat pumps are challenging the market construction. While any citizen driven effort to produce energy locally is welcome, the concern is at that this could lead to sub-optimisation and could endanger the cost-efficiency of the joint energy system risking unjust conditions for the poorer segments of society.

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Therefore, the most relevant aspects of PED in Copenhagen are sector integration and introduction of a higher degree of flexibility allowing demand and supply to follow each other. This goes for both electricity and heat.

Recent regulatory changes have also made it economically viable to a much higher extent to exploit surplus heat from for example supermarkets.

As a capital it is highly unlikely that Copenhagen under any circumstances would be able to meet its own energy demand with production inside the city borders. Never-the-less Copenhagen intends to try to realise the socio-economic potential for local production. Roof based PV is thus encouraged and will be part of the energy vision 2035. And with the introduction of roof-based PV follows a discussion on ownership forms and market access.

And similarly, electric transport will pose new challenges and opportunities.

The idea of PED is relatively straight forward when considering a new area in the city. Here the decision-makers will often be the professionals developing the area. But the existing buildings in the city outnumber the new by far, and also need to be addressed if sustainability goals are to be reached. Here the PED concept has inspired an idea to a new approach that can empower the local population, businesses, and institutions. The starting point would be the local community in a clearly defined district and what they are interested in pursuing to achieve greater sustainability. The input would among other be various GIS and non-GIS dataset that can be used to assess each district by topic. A topic could for example be the heat profile of the district (energy labels, building renovation, district heat supply temperatures etc.) combined with various socio-economic data, mapping of organisations, etc. Another topic could be related to food and dietary habits. And so on. With the mapping, the municipality would be able to approach a district and facilitate that the local democracy take action. Copenhagen has recently formulated a first project to test this approach. The focus of the project will be how to make buildings flexible consumers/prosumers and prepare them for lower district heating temperatures. The buildings are municipal, private, and social.

4.6. Krakow

4.6.1. Process followed for city vision development

Krakow City Vision 2050 was created on the basis of predictions, supported by arguments, developed by specialists in various fields and representatives of many stakeholder groups. Representatives of universities, district councils, municipality and independent civic organizations took part in the process. The proposed directions of the City's development were enriched by concepts developed in European metropolises with equally ambitious plans towards sustainable development.

Taking into account the climate crisis, the need to transform the city is inevitable. It is necessary to mobilize the efforts of many: residents, scientists, entrepreneurs, local government officials, urban planners and many others, in order to adapt the urban structure to the dynamically changing reality. Changes in thinking, attitudes and behaviour are needed.

In 2019, Krakow became the first city in Central and Eastern Europe to take on an ambitious and pioneering challenge: to join the unique European HCC DD (Health Clean Cities Deep Demonstrations) program, coordinated by the Climate-KIC organization and funded by a grant from the European Institute of Innovation and Technology. The goal of the project was to create

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a transformation strategy aimed at achieving climate neutrality (a zero-carbon city), i.e. reducing harmful greenhouse gas emissions to a minimum. As part of this activity, numerous workshops and meetings were held, including mapping the city's carbon footprint by identifying key problems, barriers, opportunities and actions implemented in categories such as construction, mobility, energy, food, society. During the 2 days of workshops, more than 300 remarks, comments, opinions and ideas on the city's emission system were collected.

The city regularly involves residents in the processes of creating strategic directions for the city. There are public consultations, workshops, informational meetings, and telephone standbys. Residents and other stakeholders are kept informed of this opportunity through announcements on official city hall websites, social media, public transportation and bus shelters.

An important action of the City was to conduct the first Krakow Climate Panel in 2020 - 2021.The Climate Panel is a form of deliberative democracy. It is a way of making important decisions by a randomly selected group of local citizens, whose role is an in-depth analysis of a given matter, a deliberation over different solutions and help in making rational decisions, taking into account the common good. This group is intended to reflect the general population – the members are chosen in terms of demographics, such as age, gender, place of residence and education level. The essence of the citizens' assembly is to develop recommendations based on the best available knowledge and after getting acquainted with the views of all interested parties. Kraków decided to organise this Assembly on climate change, to achieve this aim of zero-emission city, as soon as possible under conditions of a fair, effective and socially acceptable transformation. However, it is not possible without appropriate national regulations and programmes, but also involvement of the local community: residents, social entities, entrepreneurs and the scientific community. Before the Assembly had started recruiting for panelists, public consultations took place. Over 200 people had participated in information meetings and workshops and over 300 comments were collected – in further work on the panel, the organisers took into account all the suggestions. As part of these meetings, all interested residents could listen to presentations about climate transformation, citizen engagement as well as buildings and energy sector. The lively discussions showed that residents are becoming more and more aware of their role in the fight against climate change! The result of several months of work by the Krakow Climate Panel was 100 recommendations. Ultimately, 35 were put to a vote, of which 32 received min. 80% support from participants. The recommendations are binding on the president. The main one is recommendation No. 1, which specifies the City will to achieve a **30% reduction in greenhouse gas emissions by 2030** relative to 2018, and **at least an 80% reduction in emissions by 2040**, and to achieve **climate neutrality** no later than 2050.

Many of the recommendations developed have been implemented to this day, including through the support of the ATELIER project. Recommendation No. 13, specifies the creation of a pilot project of an energy community in Krakow, along with proposing areas for its establishment, analysis of benefits, costs and limitations, and conducting an information campaign. During a series of 6 meetings conducted in 2023, together with residents, NGO's, representatives of communities, housing cooperatives and representatives of municipal institutions, we discussed the legal, technical and organizational possibilities of energy communities in Krakow. The activity was carried out as part of WP3 Innovation Atelier.

As part of WP2 in 2021, two workshops were held to discuss the City's Vison 2050. Guests from various backgrounds were invited to the workshop, such as representatives of residents - members of the District Councils of the City of Krakow, associations and organizations,

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representatives of the Krakow Municipality and municipal units and scientists with different background. The 1st workshop was divided into thematic blocks: 1) SWOT analysis, 2) discussion about global trends, 3) discussion "What city would we like to live in in 2050?". The strategic question posed to the workshop participants was: "What city would we like to live in in 2050?". The teams were very ambitious in defining the "Vision of the City 2050", where the main emphasis was on the development of transport and municipal infrastructure as well as spatial order. The 2nd workshop was dedicated to creation of different city qualitative scenarios: pessimistic, middling, optimistic and finally master scenario.

Along with conducting numerous workshops, a great number of information activities and meetings with residents are also conducted on a regular basis. From 2022, the City has been running the campaign, "Krakow in a good climate", which through various forms: educational films, discussions with seniors, pro-climate events, residents have become aware of self-actions to reduce greenhouse gas emissions. A special, "Climate" tab on the city's website was launched in 2021, where articles on climate are regularly published.

Even though we have already done a lot of work, we are not slowing down. We are carrying out ambitious projects and initiatives. In 2023, Krakow joined the Mission of 100 climate-neutral cities by 2030 and initiated work on SECAP and CCC.

4.6.2. City Vision

In 2050 Krakow is a climate-neutral and green city. Comfortable to live in and friendly, also for people with special needs. Vibrant with residents' activity, thriving thanks to innovative and competitive entrepreneurs. Krakow is a leader in the energy transition and a model for other cities.

In 2050, the majority of Małopolska residents live in large cities, primarily in Krakow. As such, it has become necessary to adequately adapt the urban structure and meet many urban, technological and environmental challenges. Architectural solutions have been implemented, pedestrian routes have been adapted, and urban transport has been improved – all these ensure that every resident can freely enjoy the urban life. The city is safe, efficient and comfortable to live in thanks to the efforts of many communities and the consistent implementation of policies, strategies and plans for clean air, climate change adaptation, noise protection and transport infrastructure development.

Krakow is a city of dialogue and cooperation, where residents are aware of progressive climate change, its causes and effects. They persist in taking various pro-climate measures: they save water and energy, make informed purchasing choices and reduce waste generation. The system of public consultation has been expanded, so they have a real impact on the reality

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around them. Active community-based organisations initiate actions, which they then implement in cooperation with the city authorities.

Residents are open to new solutions, have a sense of responsibility and agency, and all these translate into the implementation of ambitious individual initiatives for the environment.

Local government administration acts as a role model for citizens. It carries out successful pilot, demonstration projects that contribute to the changes in the attitudes of entrepreneurs, institutions and residents. Numerous pro-environmental events are being organised, engaging all citizens to intensify environmental activities. The city authorities are guided by the community welfare, environmental well-being, and the need for development.

Krakow is a city of innovation and entrepreneurship, which has become an attractive metropolis for investors, and is distinguished by its competitiveness in many fields in both the European and the global markets. State-of-the-art solutions are developed, tested and implemented here. A cooperation platform bringing together entrepreneurs from different sectors has been launched to accelerate the exchange of knowledge and experience. This has led to the rapid development of advanced equipment, and thus, stimulated the local technology market. Krakow entrepreneurs collaborate strongly with the city authorities and the scientific community in the process of building an independent energy mix.

Krakow as a Scientific Centre. Vibrant scientific community plays a significant role in the city transition. Numerous cooperation initiatives are undertaken with scientific centres in Poland and around the world. Inter-university sectoral knowledge-sharing platforms have been created, where state-of-the-art solutions are jointly developed, with a significant impact on the technology market. A number of independent R&D centres have been founded. Strong cooperation has been established between local entrepreneurs and the public administration. Access to knowledge and ongoing projects has been improved. Higher education institutions are models of green attitudes for the student community, shaping the environmental sensitivity of young people.

Krakow has become an attractive place to live for highly-skilled professionals.

Krakow as an advocate for society. Continuous attempts are made to influence legislative decisions at the national level on climate protection, greenery and clean air. The widespread involvement of residents, entrepreneurs and local leaders in environmental and climate issues has led to the creation of a metropolitan governance system that prioritizes just transition while mitigating climate change.

Krakow as a zero-emission city is a pioneer of decarbonisation among Central and Eastern European cities. Greenhouse gas emissions have been reduced as much as possible, and this has gone hand-in-hand with increasing the ability to absorb CO_2, so as to offset those emissions that could not have been reduced for technical reasons. Compensation measures have also been implemented. Local renewable energy resources are used to the maximum extent. Numerous energy communities and cooperatives as well as energy clusters have emerged, jointly forming integrated local energy collectiveness. With the help of favourable legislative changes at the national level, new business and financial models for RES development have been successfully developed and implemented. District heating is a smart centralised system and reaches densely built-up areas. It provides residents with thermal energy from 100% zero-emission energy sources. Areas of dispersed housing are dominated by private systems of renewable energy. The Energy Management Platform has been

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developed; it draws on up-to-date data on energy consumption in all buildings (smart building system), distributed energy generation and available capacity in energy storage facilities, allowing for real-time coordination of energy flow in the system.

All energy consumed in the city comes from zero-emission sources.

Thanks to the commitment of building owners and managers, numerous support programmes that have been implemented, as well as climate standards and financing mechanisms that have been developed, in 2050 the majority of buildings are NZEB or PEB.

All office buildings have multi-criteria certifications. Materials used in the construction of new civil structures consist mainly of local products with a low carbon footprint and reused demolition materials. The requirement of material passports for new development projects has been successfully introduced.

Appropriate financial models have been implemented to accelerate the thermal modernisation of the built-up quarters. In several parts of the city, there are energy-positive districts, which serve as a model for the application of available technical solutions and business tools. The modernisation activities have been carried out in alignment with the historical fabric of the city, without any detriment to the historical value.

In 2050, most buildings are near-zero-energy buildings.

Krakow as an electromobility city. The routes of both trams and the Fast Commuter Rail have been expended, and additional lines of collision-free rail transport have been constructed. The transport system within the city has been fully integrated (public transport, local carriers, rail). The extensive network of bicycle and pedestrian paths together with efficient public transport have led many residents to give up their cars. Most of the unused parking areas have been transformed into green spaces. The city strategy towards sustainable urban mobility has delivered the expected results, namely an integrated, well-organised transport system. The Clean Transportation Zone has been introduced throughout the city, and as a result, the majority of fossil-fuel vehicles have been replaced with electric cars and a network of charging stations has been developed. All city vehicles use green energy from RES, biogas or hydrogen propulsion.

Most of the unused parking areas have been transformed into green spaces.

Krakow as a zero-waste city. The impact of the city activities on the environment is negligible. Entrepreneurs, residents and institutions are guided by the idea of zero waste in their daily activities, making informed purchases, generating trace amounts of waste and making the most of local food resources. It has become common to limit the consumption of meat.

Krakow as a green city, providing habitat for many plant and animal species. A network of urban parks has been expended; they are local meeting places and provide protection for natural resources and the environment. The city resilience to climate change has been strengthened with improvements to the flood protection system and increased biodiversity. The urban heat island effect has been minimised. It has become a standard to use green infrastructure, such as rain gardens, green roofs and walls, and to take advantage of the sustainable rainwater management, including through the use of materials that allow water to be retained in the ground. Buildings have retention tanks so that the reclaimed rainwater is used for watering the garden or for sanitary purposes.

Increased access to green spaces has improved the quality of residents' life.

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Krakow as a city comfortable to live in. The entire area of the city is covered by local land-use plans, which ensures coordination of interactions between the natural environment, communication, urban planning, the socio-economic system and residents' needs. The post-industrial areas have been transformed into a modern urban fabric with its all necessary components: greenery, infrastructure or accessibility for people with disabilities. The idea of a 15-minute city has been successfully implemented, with residents meeting basic needs within a quarter of an hour from their homes. Undeveloped urban areas have been turned into green spaces for recreation, artistic activities and creativity. Available planning tools allow intelligent scheduling, coordination and monitoring of development projects. The multi-criteria experience of experts and scientists is used at the project planning stage. The city regularly acquires new land to convert it into green spaces.

Krakow is a safe and smart city, where many activities are automated, and this leads to achieving significant energy savings, as well as maximum efficiency and stability of operations. Large-scale digitization has made many activities in the city fully automatic. The public transport system is continuously being monitored and adapted to changing conditions. Trams and collision-free rail transport are unmanned. Most administrative matters can be done online. Strategic decisions are made based on real data. A special tool, 'Virtual Twin of Krakow', has been created to model the impact of test changes on the city functioning. The widespread use of information technology will ensure better and optimised services for citizens.

Krakow is a model for many European cities on how to implement plans and strategies to achieve architectural, social, economic, community, cultural, technological and environmental balance. It has successfully acted as a legislative sandbox, leading to the development of legal solutions scalable for other local governments. The City Authorities share their just transition experience and provide support to other Cities in Poland through a number of cooperation platforms.

4.6.3. Master scenario

Krakow Master scenario is aligned with the Climate City Contract 2030 targets set by the municipality, while the 2030-2050 period is completed with the Atelier 2050 City Vision. To model Krakow Master scenario, the LEAP city energy model has undergone a series of modifications as new data has been available. First, base year has been updated from 2018 in the previous version to 2021 in this new version. The model structure has been also further detailed, including the breakdown of the building sector into residential, municipal, and private tertiary buildings, the consumption from the industry sector, more detail regarding public lighting, and updated information concerning transport sector. Finally, BaU scenario has been aligned with the one presented in the CNC Krakow model, a supporting tool owned by the city for the Climate City Contract initiative. Therefore, Krakow Master scenario is based on this new diagnosis and Bau scenario and takes into account the city's new starting point and updated baseline trends while modelling specific measures, actions and policies aimed at achieving the City Vision.

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Table 22. Achieved energy savings in Krakow Master scenario.

SECTOR	2021 (GWh)	2030 % reduction with regard 2021	2050 % reduction with regard 2021
Residential	4.629	-7%	-35%
Private tertiary buildings	3.962	-3%	-15%
Municipal buildings	216	-10%	-42%
Street lighting	34	-30%	-64%
Industry	3.999	-3%	-15%
Municipal fleet	0,001	-27%	-73%
Passenger transport	1.869	-46%	-62%
Freight transport	1.188	-56%	-68%
TOTAL	**15.896**	**-13%**	**-31%**

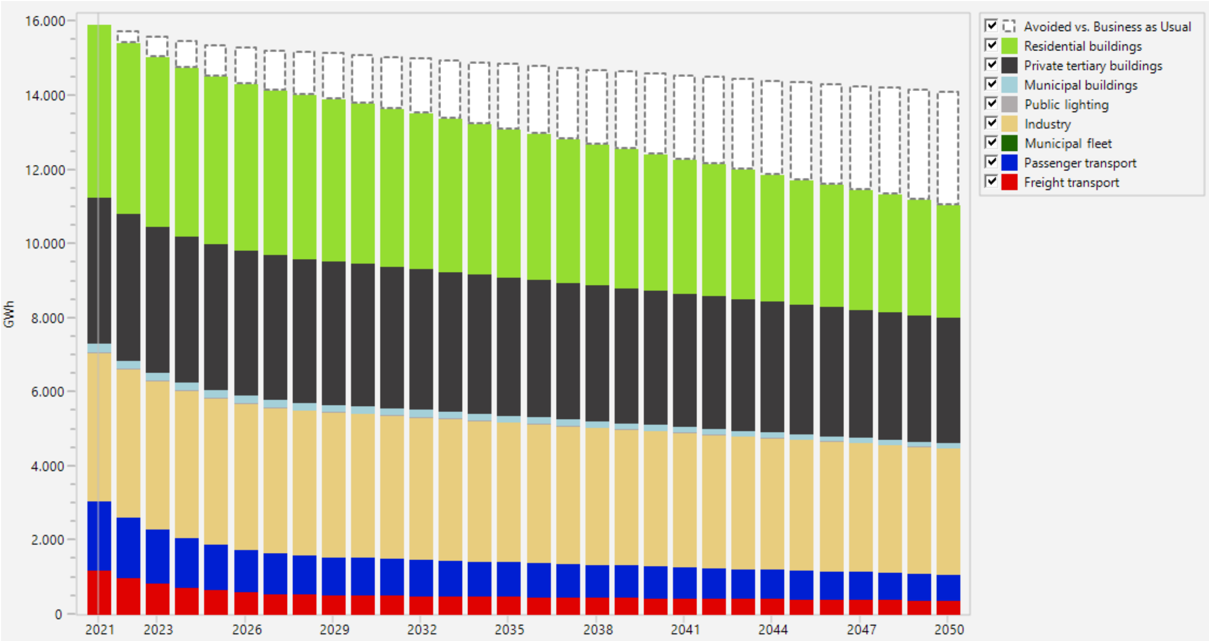

Figure 44. Krakow energy consumption by sector in the Master scenario.

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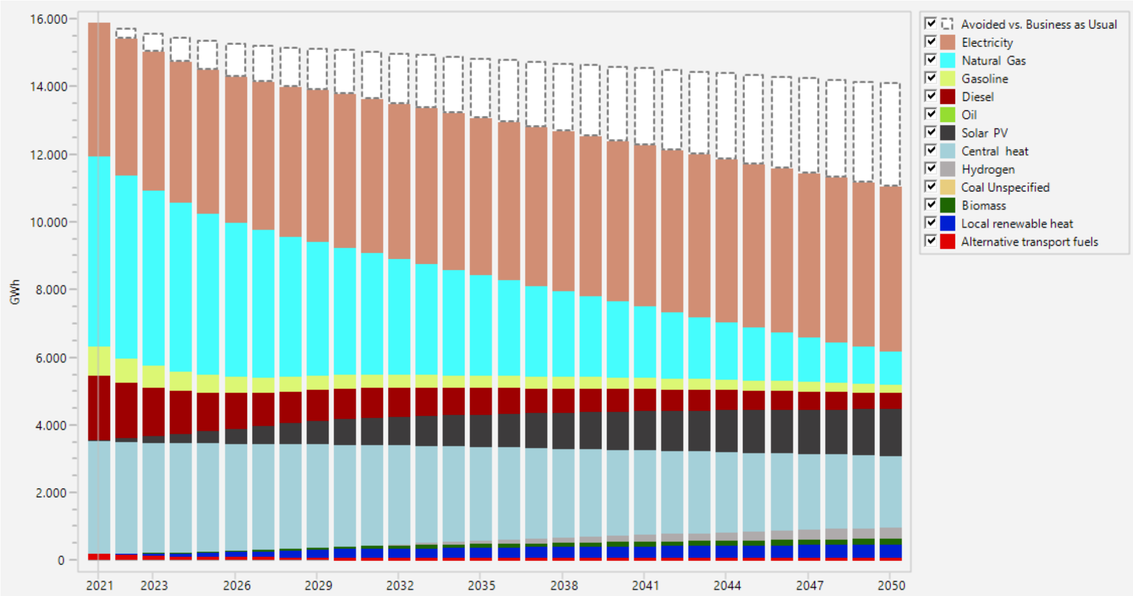

Figure 45. Krakow energy consumption by fuel in the Master scenario.

Regarding GHG emissions, electricity emission factor in the CNC model (and therefore also in LEAP model) is assumed to be the national grid one, since local production can be assumed negligible compared to imported electricity. According to one of the main national electricity suppliers[20], national grid emission factor could be assumed to be drastically reduced thanks to the increase in renewable energy capacity by 520% (amongst other things, due to investments in the construction of photovoltaic farms, onshore wind farms and participation in projects related to the construction of wind farms in the Baltic Sea). Carbon neutrality in national grid is expected to be achieved by 2050. Regarding the local heat network, a partial decarbonisation is assumed by 2030 due to the transformation of the CHP plants to use not only coal, but also gas. Additionally, heat pumps will be much more widely used. Increasing energy from waste will also be an important element of the energy mix. DH is also fully decarbonised by 2050 (see section 0).

Table 23. Considered emission factors for electricity and heat from DH in Krakow Master scenario.

FUEL	2021	2030	2050
Electricity (ton CO2/MWh)	0,907[21]	0,398	0
Heat (DH) (ton CO2/MWh)	0,408	0,214	0

Considering the decarbonisation of both heat and power networks, 781 kton CO2 (from tansport, industry, and waste management) should still be compensated in Krakow Master scenario to achieve full carbon neutrality.

[20] https://e-puls.tauron.pl/informacje/751973/strategia-grupy-tauron-na-lata-2022-2030-z-perspektywa-do-2050-roku
[21] https://app.electricitymaps.com/zone/PL

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Table 24. Achieved GHG[22] savings in Krakow Master scenario.

SECTOR	2021 (kton CO2)	2030 (kton CO2)	2050 (kton CO2)
Residential	1.986	1.004	0
Private tertiary buildings	2.617	1.175	0
Municipal buildings	104	41	0
Street lighting	31	9	0
Industry	1.263	916	194
Municipal fleet	0,0003	0,0002	0
Passenger transport	528	274	124
Freight transport	317	137	91
Waste	151	129	129
Industry process emissions	830	244	244
TOTAL	**6.846**	**3.929**	**781**

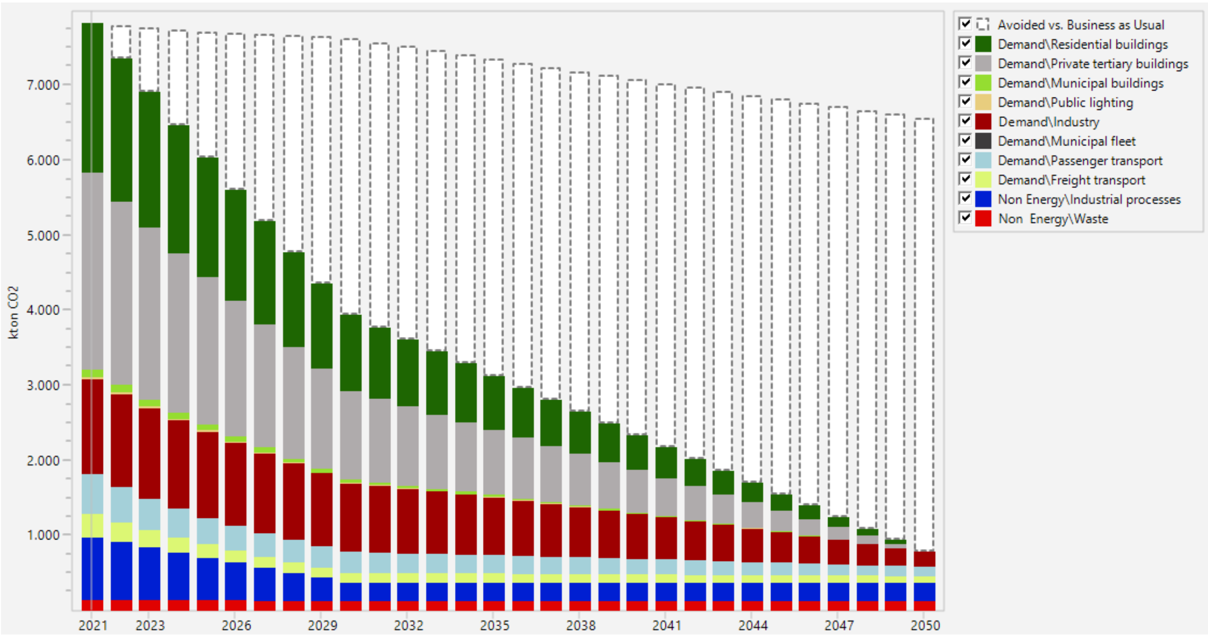

Figure 46. Krakow GHG emissions by fuel in the Master scenario.

Next sections describe the assumptions and specific sectoral results of the Krakow Master scenario.

Residential buildings

According to the City Vision, the current residential stock should be renovated at a 3% yearly rate (i.e. 3% of the current total gross floor area to be renovated each year), reaching a 87%

[22] Note that GHG emissions in all figures and tables for the Budapest Master scenario reflect a scope 2 assessment. That is, power and heat generation emissions are allocated to the final energy consumption of electricity and heat in end-use sectors.

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renovated stock by 2050. Regarding new households, a 1% yearly construction rate as in the BaU scenario has been considered.

Table 25. Energy intensity (in MWh/m2) by household type in Krakow Master scenario.

Household type	Energy intensity (kWh/m2)
Existing households	165
Renovated households pre 2030	99
Renovated households post 2030	66
New households pre 2030	45
New households post 2030	15

The renovation of households considers both the renovation of the building's envelope and the renovation of heating systems, hence implying a change in the fuel mix and achieving the full decarbonisation of the residential sector thanks to the phase out of fossil fuels, the use of carbon-free electricity from the national grid and the full decarbonisation of the local heat network.

Table 26. Starting and final fuel mix in the residential sector in Krakow Master scenario.

	2021	2030	2050
DH	45,21%	45%	43%
Natural gas	35,09%	15%	0%
Local renewable heat (e.g. biomass, solar thermal)	0%	3%	5%
Electricity	19,16%	27%	32%
Electricity from solar PV	0,54%	10%	20%

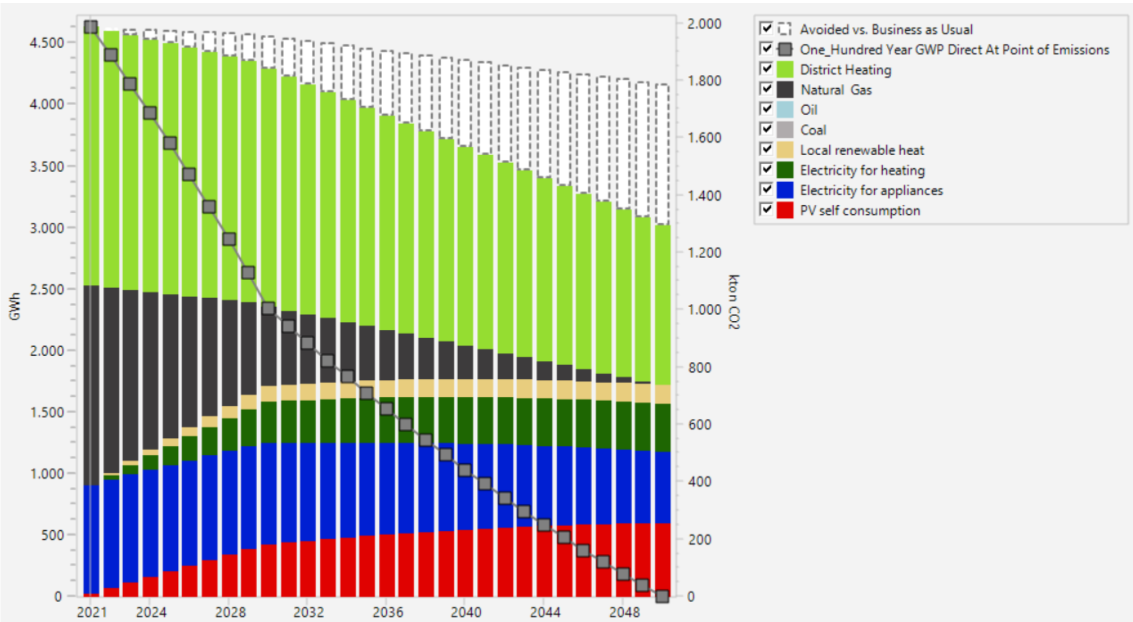

Figure 47. Residential energy consumption and GHG emissions in Krakow Master scenario.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 864374.

Private tertiary buildings

According to the City Vision, the current private tertiary buildings stock should be renovated at a 2,5% yearly rate (i.e. 2,5% of the current total gross floor area to be renovated each year), reaching a 72% renovated stock by 2050. Regarding new buildings, a 1% yearly construction rate as in the BaU scenario has been considered.

Table 27. Energy intensity (in kWh/m2) by private building type in Krakow Master scenario.

Building type	Energy intensity (kWh/m2)
Existing buildings	82
Renovated buildings pre 2030	49
Renovated buildings post 2030	33
New buildings pre 2030	22
New buildings post 2030	7

The renovation of buildings considers both the renovation of the building's envelope and the renovation of heating systems, hence implying a change in the fuel mix and achieving the full decarbonisation of the private tertiary sector thanks to the phase out of fossil fuels, the use of carbon-free electricity from the national grid and the full decarbonisation of the local heat network.

Table 28. Starting and final fuel mix in private tertiary buildings in Krakow Master scenario.

	2021	2030	2050
DH	20,67%	18%	15%
Natural gas	20,33%	14%	0%
Local renewable heat (e.g. biomass, solar thermal)	0%	3%	7%%
Electricity	59%	60%	66%
Electricity from solar PV	0%	5%	12%

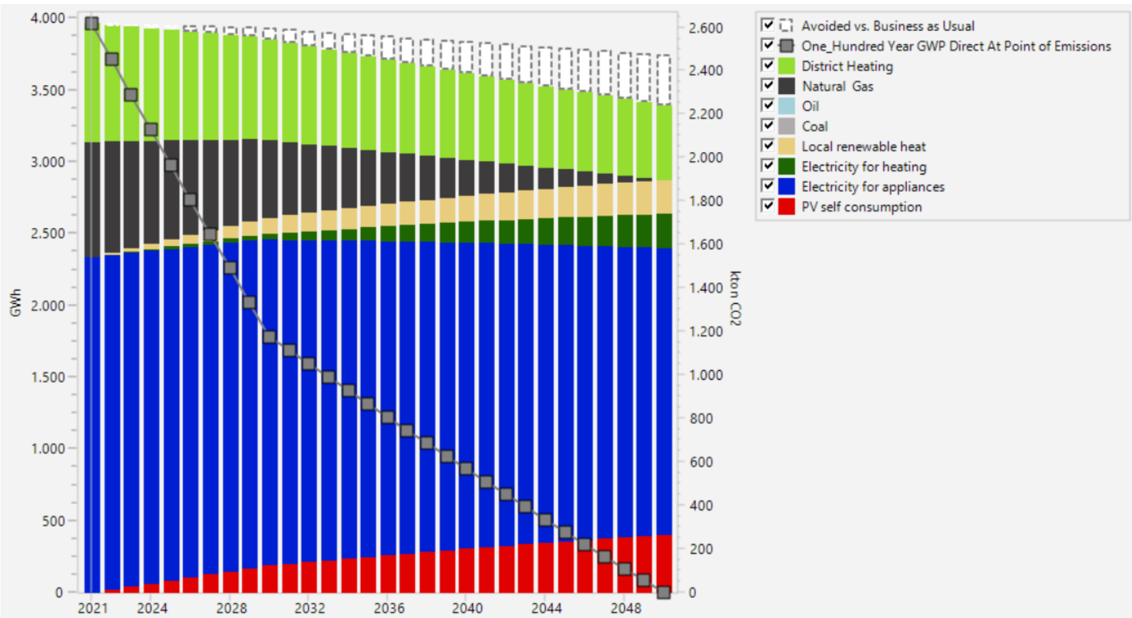

Figure 48. Private tertiary buildings energy consumption and GHG emissions in Krakow Master scenario.

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Municipal buildings

According to the City Vision, the current municipal buildings stock should be renovated at a 3,5% yearly rate (i.e. 3,5% of the current total gross floor area to be renovated each year), reaching a 100% renovated stock by 2050. Regarding new buildings, a 0,5% yearly construction rate as in the BaU scenario has been considered.

Table 29. Energy intensity (in kWh/m2) by municipal building type in Krakow Master scenario.

Building type	Energy intensity (kWh/m2)
Existing buildings	114
Renovated buildings pre 2030	68
Renovated buildings post 2030	46
New buildings pre 2030	31
New buildings post 2030	10

The renovation of buildings considers both the renovation of the building's envelope and the renovation of heating systems, hence implying a change in the fuel mix and achieving the full decarbonisation of the private tertiary sector thanks to the phase out of fossil fuels, the use of carbon-free electricity from the national grid and the full decarbonisation of the local heat network.

Table 30. Starting and final fuel mix in municipal buildings in Krakow Master scenario.

	2021	2030	2050
DH	69%	64%	60%
Natural gas	12%	5%	0%
Local renewable heat (e.g. biomass, solar thermal)	0%	0%	0%
Electricity	19%	16%	17%
Electricity from solar PV	0%	15%	23%

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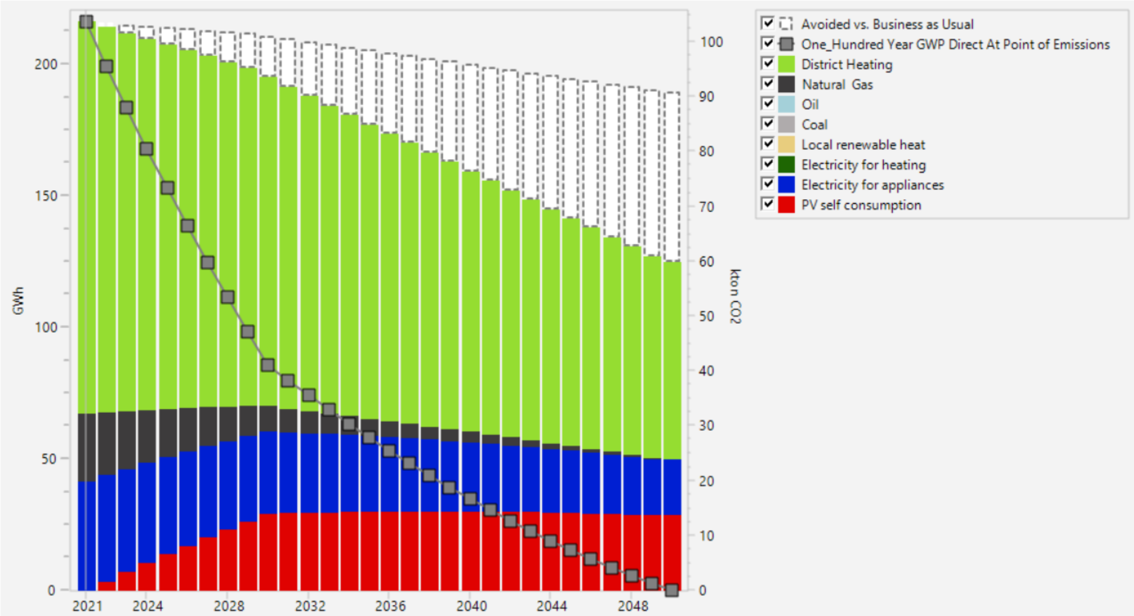

Figure 49. Municipal buildings energy consumption and GHG emissions in Krakow Master scenario.

Street lighting

Krakow Master scenario assumes that 60% of the city street lamps stock is replaced by LED technology by 2030, reaching a 100% by 2050. Since the full decarbonisation of the national grid is assumed by this year, street lighting is carbon-free by 2050.

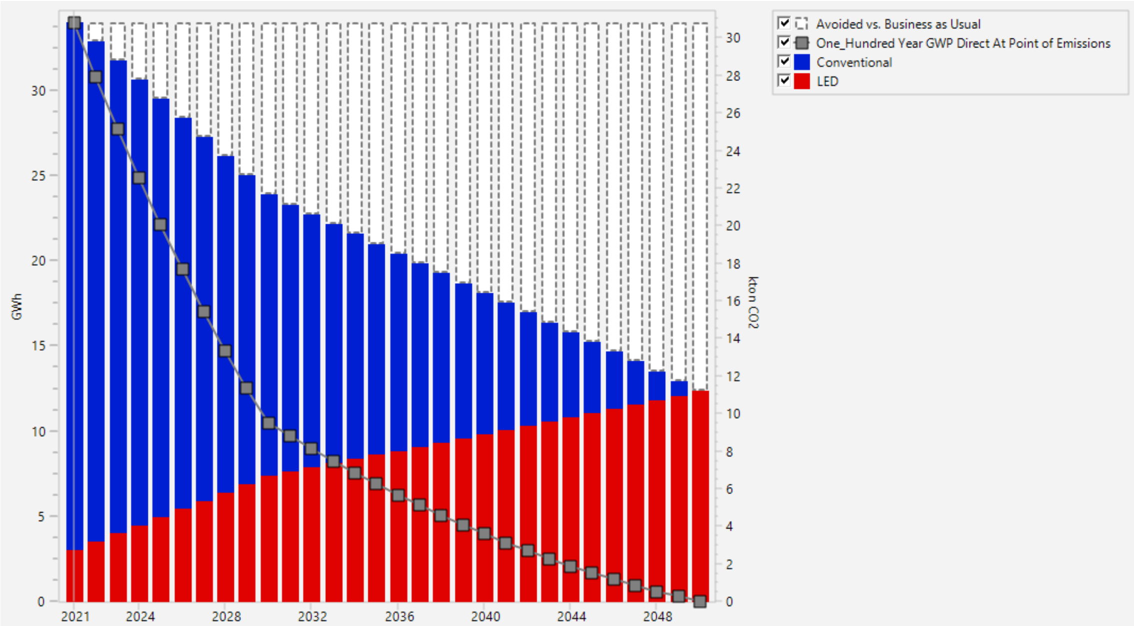

Figure 50. Street lighting energy consumption and GHG emissions in Krakow Master scenario.

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Industry

Assuming the implementation of energy efficiency measures in the industry sector, a 3% and 15% energy reduction with regard the base year has been considered by 2030 and 2050 respectively in the Krakow Master scenario. In addition a shift in the fuel mix of the sector has been considered with the gradual replacement of natural gas by cleaner fuels like biomass and H2. The sector is also further electrified, with the fostering of solar PV technologies too. However, although power and heat networks are considered carbon-free by 2050, natural gas is not fully removed and therefore the sector is not fully decarbonised at the end of the scenario timeframe. Moreover, industry process emissions should be also considered, summing up 830 kton by 2021 and 244 kton by 2030 and 2050. These should be added to the energy-related emissions represented in Figure 51.

Table 31. Starting and final fuel mix in the industry sector in Krakow Master scenario.

	2021	2030	2050
DH	6,78%	6,78%	6,78%
Natural gas	78,87%	66,05%	28,22%
Oil	0,13%	0%	0%
Coal	0,08%	0%	0%
Biomass	0%	2%	5%
Hydrogen	0%	0%	10%
Electricity	14,14%	22,16%	40%
Electricity from solar PV	0%	3%	10%

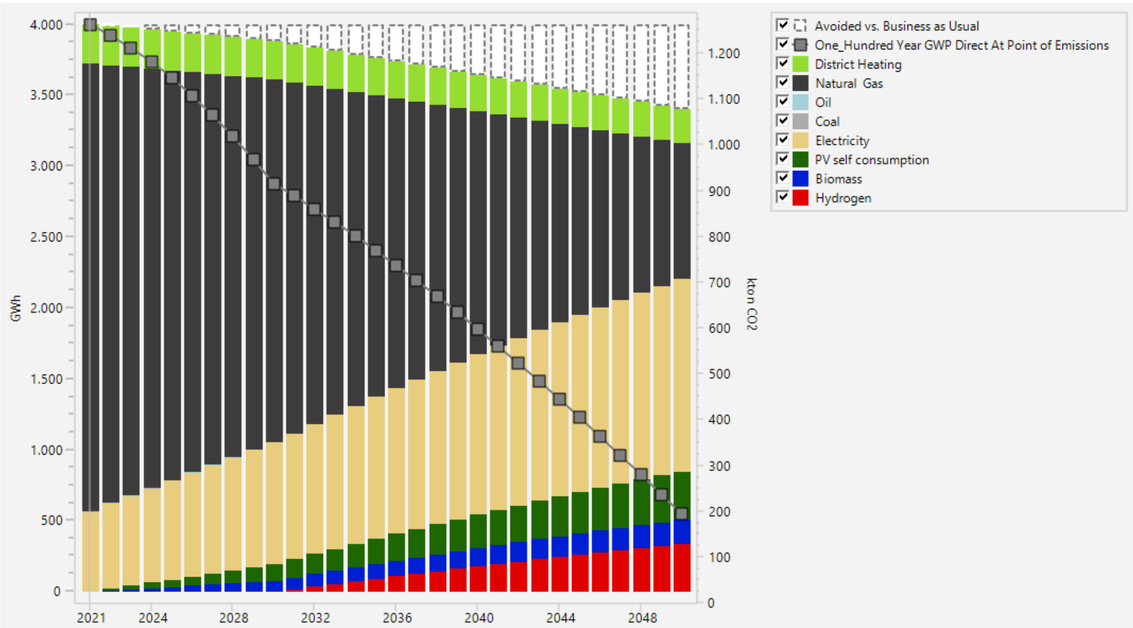

Figure 51. Industry energy consumption and GHG emissions in Krakow Master scenario.

Municipal fleet

As a result of the optimisation in the operation of municipal vehicles fleet a 0,5% yearly reduction in the consumption of vehicles of the municipal has been assumed, whereas the

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share of electric vehicles in the municipal fleet reaches 30% and 100% of the municipal vehicle stock by 2030 and 2050. The penetration of EV achieves a further energy reduction as well as the full decarbonisation of the sector by 2050.

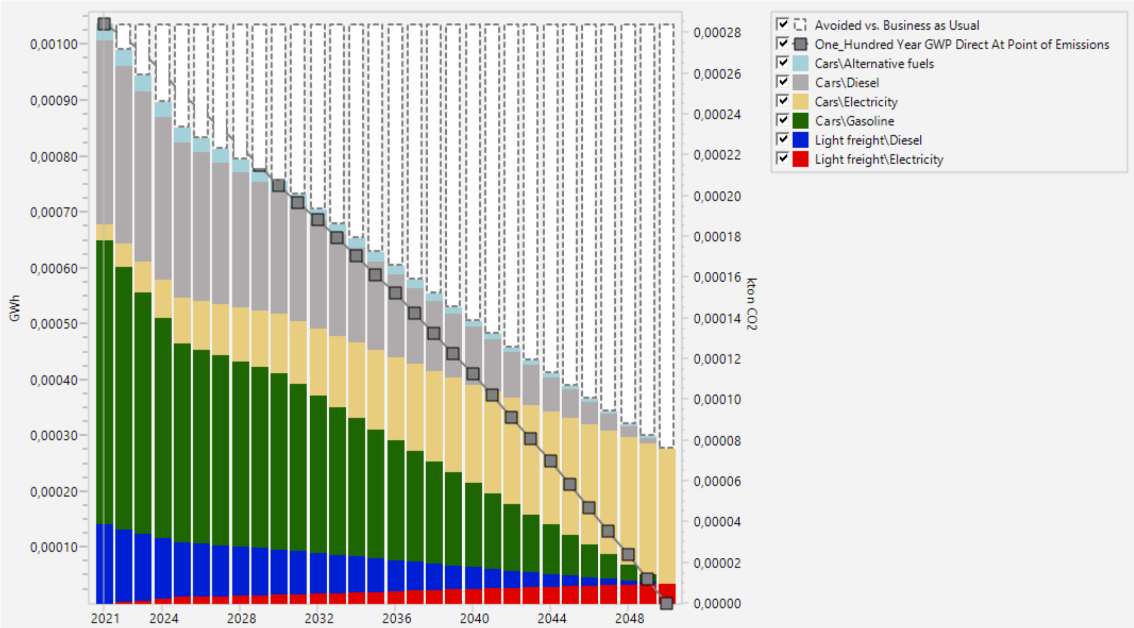

Figure 52. Municipal fleet energy consumption (by vehicle type and fuel[23]) and GHG emissions in Krakow Master scenario.

Passenger transport

Passenger transport includes both public and private transport of persons. The use of private vehicles for passenger transport is assumed to decrease as a result of the implementation of low-emission zones and other restrictions to the most pollutant vehicles, the shift to other more sustainable modes of transport such as public transport or active mobility, and other mobility-related measures. To represent this shift in mobility, vkm of private cars are reduced from 1992 Mvkm to 1033 Mvkm by 2030 (to meet CNC results) and to 934 Mvkm in 2050. In addition to the reduction of vkm, electric vehicles replace fossil-fuelled ones, contributing to the efficiency improvement and decarbonisation of the fleet. However, although public transport is fully decarbonised thanks to its full electrification by 2050 and the consideration of carbon-neutral national electricity, around 124 kton CO2 (from still running fossil-fuelled vehicles) must still be compensated to achieve the carbon neutrality of the sector.

Table 32. Penetration of EV in passenger transport in Krakow Master scenario.

	2021	2030	2050
E-cars	0,62%	8%	35%
E-buses	4%	42%	100%

[23] In the absence of further information alternative fuels include LPG, CNG, biofuels, H2…

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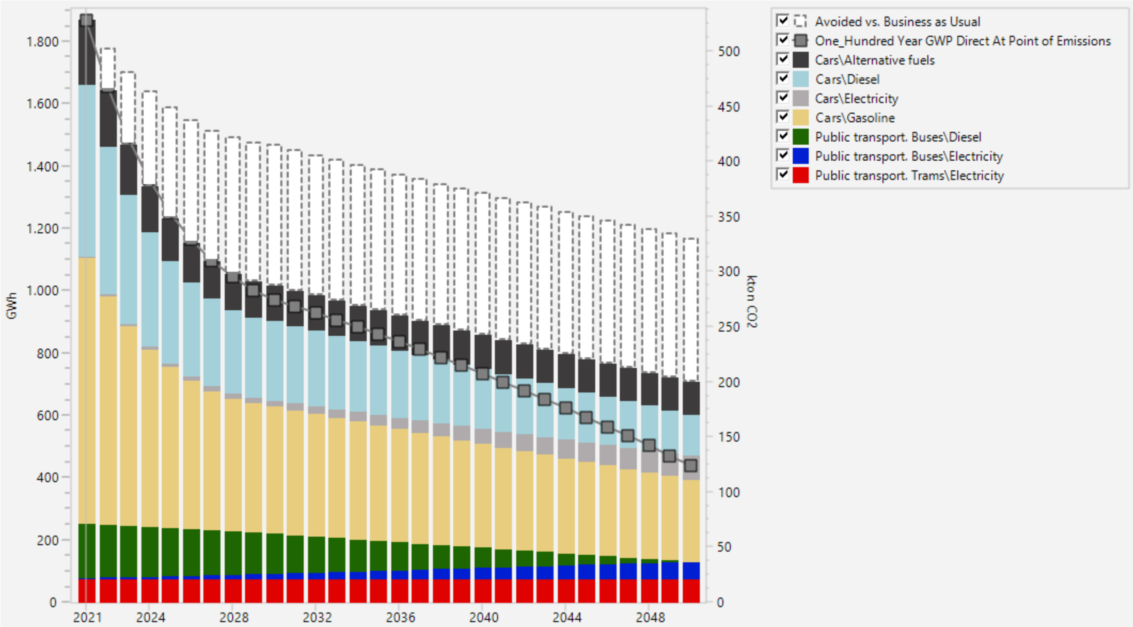

Figure 53. Passenger transport energy consumption (by vehicle type and fuel[24]) and GHG emissions in Krakow Master scenario.

Freight transport

As for the use of private vehicles for passenger transport, the circulation of freight transport vehicles is assumed to decrease as a result of mobility policies. Vkm of freight vehicles are reduced from 612 Mvkm to 282 Mvkm by 2030 (to meet CNC results) and to 255 Mvkm in 2050. In addition to the reduction of vkm, electric vehicles replace fossil-fuelled ones: 5% of freight vehicles are electric by 2030, while a 30% share is achieved by 2050. The sector is not fully decarbonisde though, around 91 kton CO2 (from still running fossil-fuelled vehicles) still requiring to be compensated to achieve the carbon neutrality of the sector.

[24] In the absence of further information alternative fuels include LPG, CNG, biofuels, H2…

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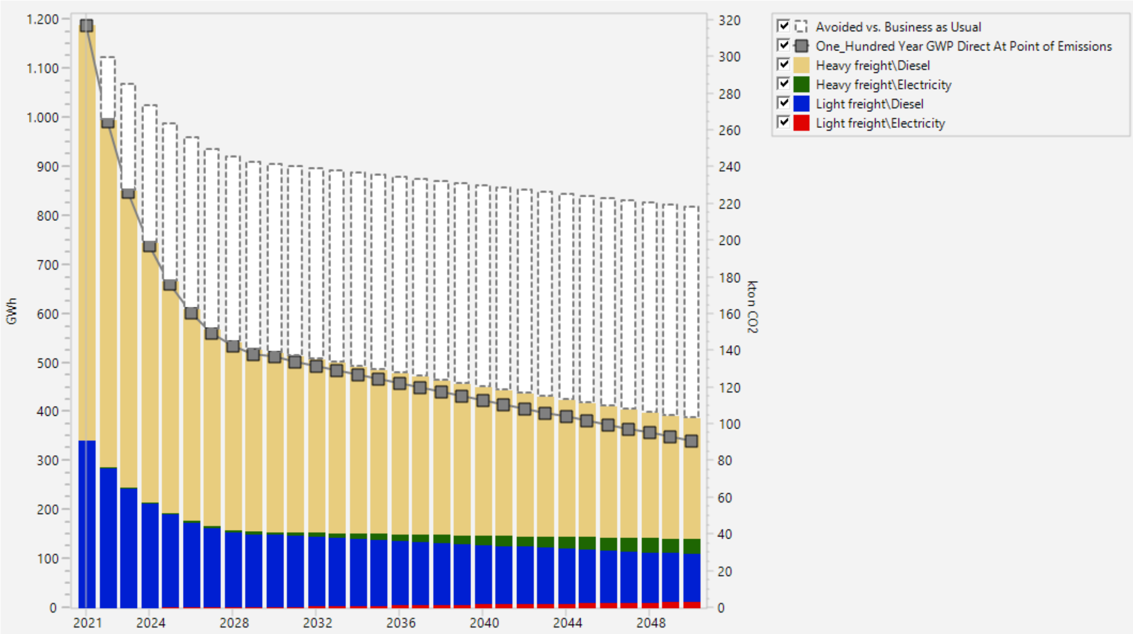

Figure 54. Freight transport energy consumption (by vehicle type and fuel) and GHG emissions in Krakow Master scenario.

Local energy generation

As discussed previously, local electricity generation represents a little share compared to the imported electricity form the national grid. Electricity production from solar PV and incineration plant will however increase in the upcoming years, reaching 320 GWh and 140 GWh production respectively by 2050. Electricity from CHP will increase in the upcoming few years, and decrease in the next 20 years, while decarbonising its input fuels (replacement of coal by cleaner fuels).

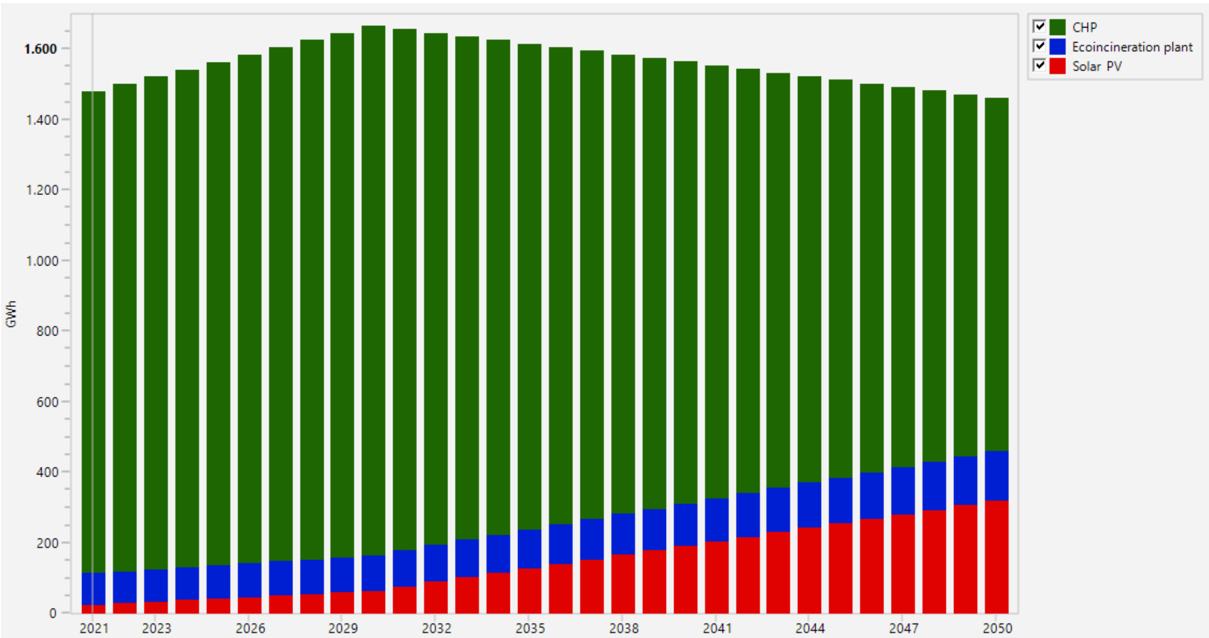

Figure 55. Evolution of local electricity generation by feedstock fuel in Krakow Master scenario.

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Concerning local heat, although the specific shares of fuels used in local generation has not been detailed, local heat network it will be based on the combination of heat pumps, waste, and the decarbonisation of CHP plants, hence achieving a carbon-free DH by 2050.

4.6.4. The role of PED in City Vision

Positive Energy District is simplistically understood as an area consisting of several buildings in which a positive energy balance is maintained, i.e. more energy is produced than consumed. In reality, however, apart from the technical, economic and organizational aspects, social issues are also important. Creating a PED together with residents will increase local ties and give a sense of agency and influence over the surrounding reality.

Creating Positive Energy Districts and Energy Positive Buildings is extremely important. Due to the high emission intensity of the construction sector (in Poland it is responsible for 37% of greenhouse gas emissions), it is necessary to implement solutions that will reduce CO2 emissions as much as possible. The implementation of sustainable practices is driven not only by increasingly stringent regulations, but also by the expectations of tenants, customers and employees in all market segments. Modernization of construction sector and creating PEDs is a complicated process. It is necessary to carry out thermo-modernization, install smart energy management solutions, but also to educate residents.

A model ideal example of PED should consist of buildings with different functions, characterized by a non-identical energy consumption profile, such as the combination of a school, a residential building and a social welfare home. Each building in the described case is characterized by a different energy consumption profile. This solution makes it possible to use the surplus electricity generated in real time from photovoltaic panels on the roof of a multi-family building, for example, to power equipment in a school or a social welfare home. The main idea of PED's is to properly manage the energy generated and the energy used. We also cannot forget to minimize energy demand, use equipment with the highest possible energy efficiency ratings and reactive power compensation devices. Due to the repeatability of the urban layout in the city, i.e. the close proximity of residential buildings to schools, health centers, cultural centers, there is a high probability of duplicating the idea of PEDs.

At the beginning of the project, various areas in Krakow were considered for which the probability of establishing a PED would be greatest. The greatest potential, both technological, organizational and social, was seen in the area of the Krakow University of Technology campus. An opportunity was seen in the university's involvement in the process of creating Kraków's first PED concept, both through its vast experience in the fields of construction, architecture, energy and, above all, for shaping the attitudes of the younger generations. Local governments should be at the forefront of the implementation of innovative activities, involving specialists especially from universities.

Krakow is a unique city, where a large part of the building stock is under the heritage. In such a case, it is definitely more difficult to introduce appropriate technical solutions, without which it is impossible to create the PED. In this case, it is important to use appropriate materials during the thermo-modernization to avoid interference with the historic fabric of the city. In addition, equipment placed on roofs is also restricted.

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Energy Positive Districts first created at specific points in the City in the future may expand with new buildings or merge with each other, establishing mutual energy relations, creating a modern, self-sufficient city in the future.

The creation of PEDs is important for the energy security of the city and the region. Generating energy locally from RES, allows to relieve the load on the electricity grid, while bringing environmental and financial benefits. Thermo-modernization of buildings, replacement of energy sources, shortening the energy transmission path allows both significant financial savings, as well as reduction of greenhouse gas emissions and reduction of local air pollution. The use of blue-green infrastructure, including: green roofs, walls and sensible rainwater management minimizes the formation of an urban heat island. When social housing developments are included in the PED, it also helps minimize energy poverty. The mentioned benefits go hand in hand with the economic development of the region, making it more attractive to investors by stimulating entrepreneurship and innovation.

In Kraków currently, attempts are being made to change local strategic planning documents in order to introduce appropriate regulations to mobilize the creation of Positive Energy Districts. Building new districts along the lines of energy self-sufficiency should also be regulated at the national level.

The area-based approach is becoming an integral part of the city's transformation toward climate neutrality. As part of the Mission of 100 Climate Neutral Cities by 2030. Krakow has initiated the NEEST project, which aims to create replication-ready solutions for thermo-modernization of different types of urban quarters with the revitalization of the areas around them.

4.7. Matosinhos

4.7.1. Process followed for city vision development

The municipality of Matosinhos has what can be considered a long-time commitment with climate action. In 2015, following the adhesion to the Covenant of Mayors for Climate and Energy, the municipality approved the first strategic documents for climate adaptation and mitigation, including the Sustainable Energy and Climate Action Plan (SECAP), which defines the main actions and measures aiming at a 40% GHG reduction in relation to 2009 (the reference year). At the end of 2021, as a result of the changes caused by the pandemic crisis, Matosinhos achieved the decarbonisation targets set for 2030, considering the objectives defined in the SECAP. Compared to 2009, carbon emissions were already reduced by 53%.

Having surpassed the objectives set by SECAP 2030 almost a decade in advance, Matosinhos established a new objective: the anticipation of carbon neutrality by 2030. This objective emerged and was reinforced at the end of 2021 with the municipality's demonstration of interest in integrating the network of 100 European cities that aim to become carbon neutral by 2030 launched under the Smart Cities and Climate Neutral Mission. Matosinhos launched the “Matosinhos Carbon Neutrality 2030” initiative, publicly announced in November 2022, which establishes the objective of reducing carbon emissions by 85% by 2030.

Aiming to anticipate carbon neutrality for 2030, Matosinhos has been developing its vision of territory based on the perspectives of its citizens, companies and most relevant stakeholders, in a co-created process that results in a common ambition: **By 2030, Matosinhos aims to be**

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a smart, sustainable, inclusive, accessible and carbon-neutral territory. In that sense, a set of collaborative sessions involving strategic stakeholders was rolled-out. The first working session with stakeholders took place in January 2023 at the Lavra parish council and was attended by representatives of the various levels of governance in the municipality, including parishes, municipal companies and services. The session was also attended by members of the municipal executive, such as the Mayor, the Councillor for the Environment and Energy Transition, the Councillor for Education, the administrator of Matosinhos Sport, the administrator of MatosinhosHabit, and the executive director of the Porto Energy Agency. In this session, participants were divided into four work groups and each of the groups focused on a specific pre-defined theme: energy, sustainable mobility, municipal action, stakeholder involvement and financing. Each of the groups presented suggestions for measures and actions to be implemented.

In May 2023, the second work session took place at the Monte de S. Brás Ecological Park. The objective of this session in particular was to involve a younger population in the discussion regarding the pathways available for achieving carbon neutrality in 2030. The session involved students from the secondary school, as well as university student, where they had the chance to present some under development projects under the topic in order to better foster discussion using a participatory approach.

A third session was realized on November 2023. In this session, several industry stakeholders were involved in the discussion, forming what can be considered to be a focus group based on the preliminary results of the first calculations of measures and actions planned on the basis of the previous sessions.

Regarding planning towards the objective of carbon neutrality for the municipality, a roadmap considering the inputs from these stakeholders has been designed, focusing in particular in areas of critical intervention as 1) energy renovation of municipal buildings, housing complexes and public lighting; 2) electrification of the municipal fleet; 3) installation of electric chargers; 4) advice on incentives for the renovation of buildings and the production of renewable energy; 5)promotion of electric mobility and 6) incentives to the use of public transport. The planning focused on the pathways necessary for achieving the goals, although also recognizing that some of the measures are already currently being implemented.

4.7.2. City Vision

The work performed by the various stakeholders over several sessions, along with different municipal companies and supported by the strong commitment of the Municipal Executive, sought to find new contributions to strengthen Matosinhos strategy on its path towards carbon neutrality in 2030. In this moment of joint reflection, participants dedicated their efforts to 4 fundamental themes: energy, sustainable mobility, municipal action and stakeholder involvement and financing. As a result of this collective work, the municipality was able to design a **City Vision for Matosinhos in 2030**, which is presented below:

Energy, urban and economic development:

By 2030, the existing public and private building stock will be mostly renovated, allowing greater thermal comfort for its residents. Renovated and new municipal social housing will play a fundamental role in Matosinhos energy and social transition.

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The new buildings built using a zero-consumption approach, as the existing buildings, will be energy self-sufficient, exporting surpluses to nearby infrastructures, forming “positive energy neighbourhoods”.

Local production combined with efficient electrical equipment, greater user awareness, the use of energy management systems and smart meters, will contribute to reduced energy dependence on third parties and will turn the use of fossil fuels marginal.

The solar thermal energy systems will also be an accessible technology to buildings in Matosinhos for heating water, minimizing the dependence on fossil fuels such as natural gas.

Urban development will occur through the valorization of outdoor spaces, with the increase of green areas and vegetation cover, renovation of existing squares and improvement of access infrastructure, highlighting the renovation of several outdoor spaces, the reforestation and requalification of the city's ecological corridor and the Leça River Corridor, among many other projects implemented by the municipality to improve common living spaces.

Local industry will be one of the main drivers of the municipality transition. The energy efficiency of industrial processes will be optimized to make production profitable, and the use of petrochemical fuels will be residual. Simultaneously, the production of renewable energy in industrial infrastructures will also be a reality as well as the incorporation of green renewable gases will help mitigate the increasingly smaller carbon footprint of this relevant economic sector.

The agricultural sector will also play an important role in the decarbonization of the territory. The energy efficiency of the facilities combined with the production of local renewable energy as well as the management and optimization of agricultural processes will contribute to the sustainability of an essential sector of activity for the region.

Municipal action, incentives and financing:

To achieve its proposed objectives, the municipality will lead by example, promoting the involvement of its actors and implementing key measures for the decarbonization of the territory.

Matosinhos will play its role in providing its citizens and companies with the necessary instruments for climate action: the energy renovation of municipal buildings, social housing blocks and the replacement of public lighting, the electrification of the municipal fleet, the installation of electric chargers, the citizen support and advice on incentives for the rehabilitation of buildings and the production of renewable energy, the promotion of mobility electricity, encouraging the use of public transport; others.

The development of local incentive mechanisms for energy retrofitting and renewable production combined by the provision of advisory services to the population will prove to be predominant measures to achieve the 2030 goals.

Governance and Public Participation:

Matosinhos will be, in 2030, a territory of active citizenship accustomed to participating in co-creation activities focused on the social and economic development of the territory and the energetic positivity of the territory.

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Based on a multi-level, integrated and collaborative governance model, the territory of Matosinhos in 2030 will be composed of urban areas organized into multifunctional neighbourhoods and rural areas where sustainable agricultural installations and forest areas predominate, responsible for carbon capture and sequestration functions.

Carbon neutrality will thus be a reality achieved by a community that, collectively, realises its responsibility in the process and acts to achieve it.

Sustainable Mobility:

In 2030, Matosinhos will be a multifunctional territory, where the population has at their disposal a set of urban sustainable mobility options.

A significant part of daily travel will be made using soft and non-polluting modes. The creation of cycling routes in the Leça Green Corridor, with a length of approximately 18 km, as well as several pedestrian routes will contribute significantly to the adoption of soft mobility for short trips. Careful urban planning also contributes to this, allowing the urban network to meet urban accessibility criteria and optimal conditions for coexistence between different modes of transport.

In 2030, an expanded, flexible, efficient and quality public transport network, including metro and buses, as well as the creation of zero-emission zones within urban areas, will make it possible to considerably avoid the use of private transport, where electric vehicles will already have a significant representation.

The turning point in the energy vector of private and public mobility will be achieved through extensive investment in an integrated electric charging network, as well as the incorporation of green hydrogen in fleets of heavy goods and passenger vehicles.

4.7.3. Master scenario

Matosinhos Master scenario has a 2030 horizon, describing the pathway followed by the city to achieve carbon neutrality. Indeed, Matosinhos municipality has decided to anticipate its objectives to achieve a carbon neutral city by 2030, in which some of the measures of the current SECAP are integrated along with other mitigation actions based on consumption data, the potential for reducing emissions and the vision of the municipality and its stakeholders. To model Matosinhos Master scenario, the LEAP city energy model has undergone a series of modifications. On the one hand, base year has been updated from 2018 in the previous version to 2019 in this new version. On the other hand, the model structure has been also further detailed, specially with the break down of the transport sector into municipal, public, and private transport fleets as well as by type of vehicle and fuel. Therefore, Matosinhos Master scenario is based on this new diagnosis, keeping the baseline trends of the BaU scenario from deliverable D2.5, while modelling specific measures, actions and policies aimed at achieving the City Vision.

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Table 33. Achieved energy savings[25] in Matosinhos Master scenario.

SECTOR	2019 (GWh)	2030 (GWh)	2030 % reduction with regard 2019
Residential	503,93	291,37	-42%
Private tertiary buildings	466,38	272,06	-42%
Public administration buildings	29,96	15,67	-42%
Street lighting	16,46	4,94	-70%
Industry	3.687,75	3.139,93	-15%
Agriculture	213,92	150,04	-30%
Municipal fleet	0,82	0,26	-69%
Public transport	25,65	16,64	-35%
Private transport	2.364,62	1.295,86	-45%
Solid waste treatment	0,52	0,26	-50%
Wastewater treatment	6,32	3,16	-50%
TOTAL	**7.313,34**	**5.190,19**	**-29%**

In line with Portugal's Roadmap for Carbon Neutrality 2050[26], the partial decarbonisation of the national power grid has been considered by 2030[27]. Hence, thanks to the electrification of the end-use sectors, and the penetration of other technologies (H2 in transport and industry, solar PV in buildings, and other renewables in buildings), the city drastically reduces its emissions by 2030. However, since the national grid is not fully decarbonised by 2030 and fossil fuels are still used (mainly in transport and industry sectors), the city would still need to compensate around 444 kton CO_2 by 2030 to achieve full carbon neutrality.

Table 34. Achieved GHG savings in Matosinhos Master scenario.

SECTOR	2019 (kton CO2)	2030 (kton CO2)	2030 % reduction with regard 2019
Residential	116,58	11,94	-90%
Private tertiary buildings	111,15	12,73	-89%
Municipal buildings	5,40	0,24	-96%
Street lighting	4,16	0,14	-97%
Industry	763,63	128,46	-83%
Agriculture	56,82	9,93	-83%
Municipal fleet	0,22	0,01	-97%
Public transport	5,82	0,47	-92%
Private transport	622,67	291,48	-53%

[25] Thanks to the data provided, energy and GHG emissions occurring outside the city boundary as a result of in-city activities have been included. Henceforth energy and GHG emissions in all figures and tables of the Matosinhos Master scenario reflect a scope 3 assessment. That is including direct emissions, indirect emissions from heat and power consumption, and outside energy/emissions resulting from in-city activities.
[26] https://unfccc.int/sites/default/files/resource/RNC2050_EN_PT%20Long%20Term%20Strategy.pdf
[27] A 28 ton CO2/GWh electricity emission factor is considered by 2030.

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Solid waste treatment	0,11	0,04	-69%
Wastewater treatment	4,69	1,75	-63%
Fugitive emissions	1,08	0,26	-76%
Waste (biological treatment & Incineration and open burning)	41,80	6,58	-84%
IPPU (Industrial Processes and Product Use)	90,48	4,03	-96%
AFOLU (Agriculture Forestry and Other Land Use)	13,24	6,32	-52%
Carbon sequestration	0	-30,70	-
TOTAL	**1.837,84**	**443,68**	**-76%**

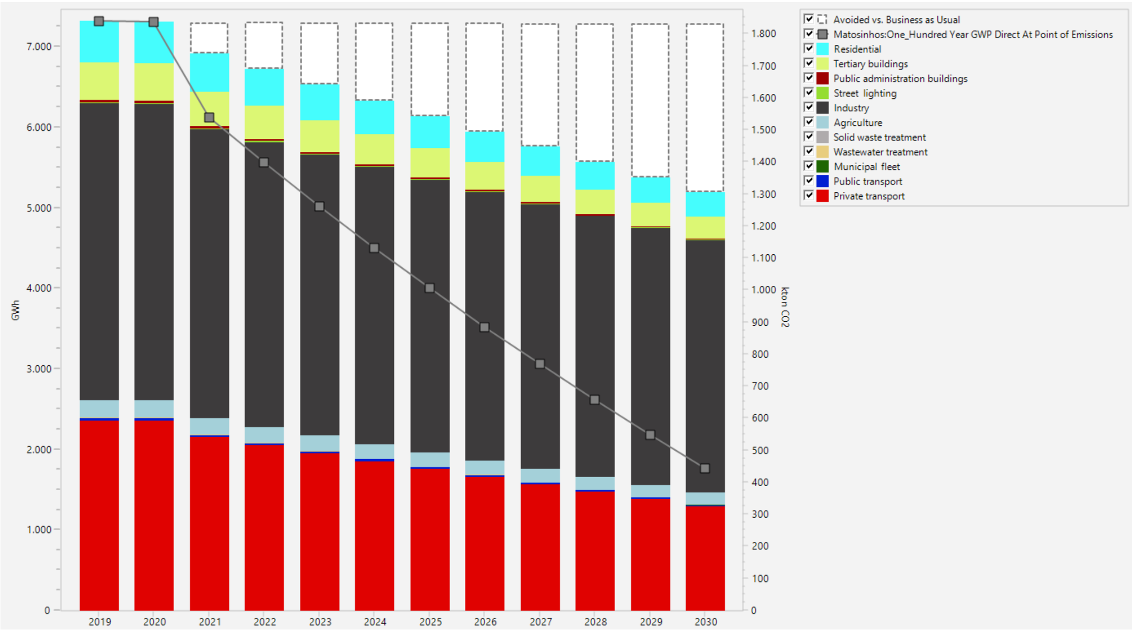

Figure 56. Matosinhos energy consumption and GHG emissions by sector in the Master scenario.

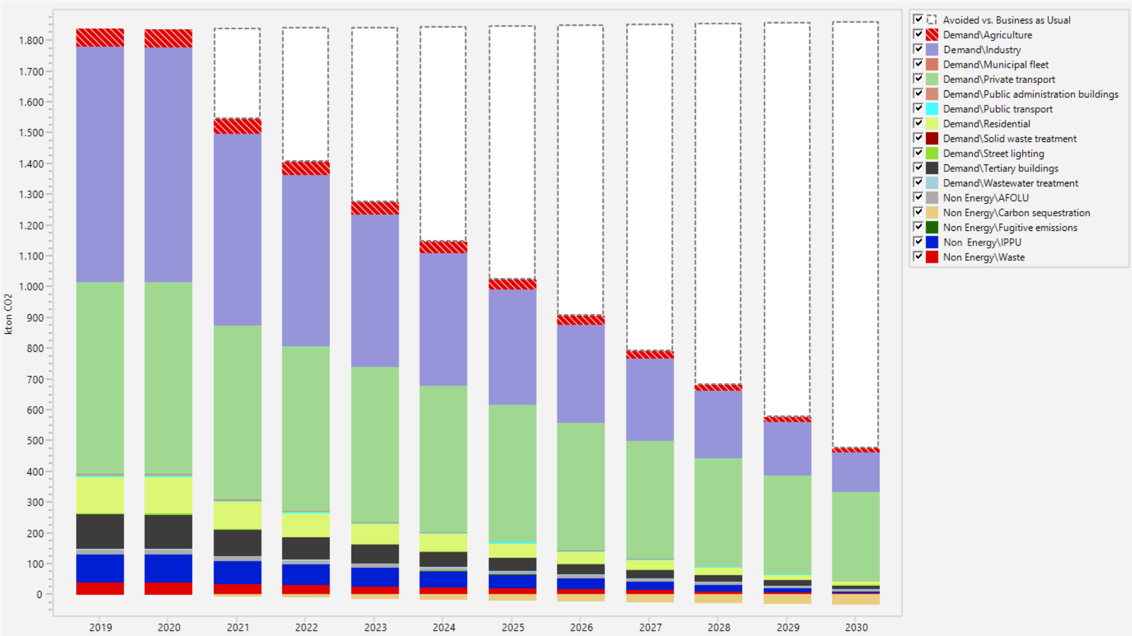

Figure 57. Matosinhos GHG emissions by sector in the Master scenario.

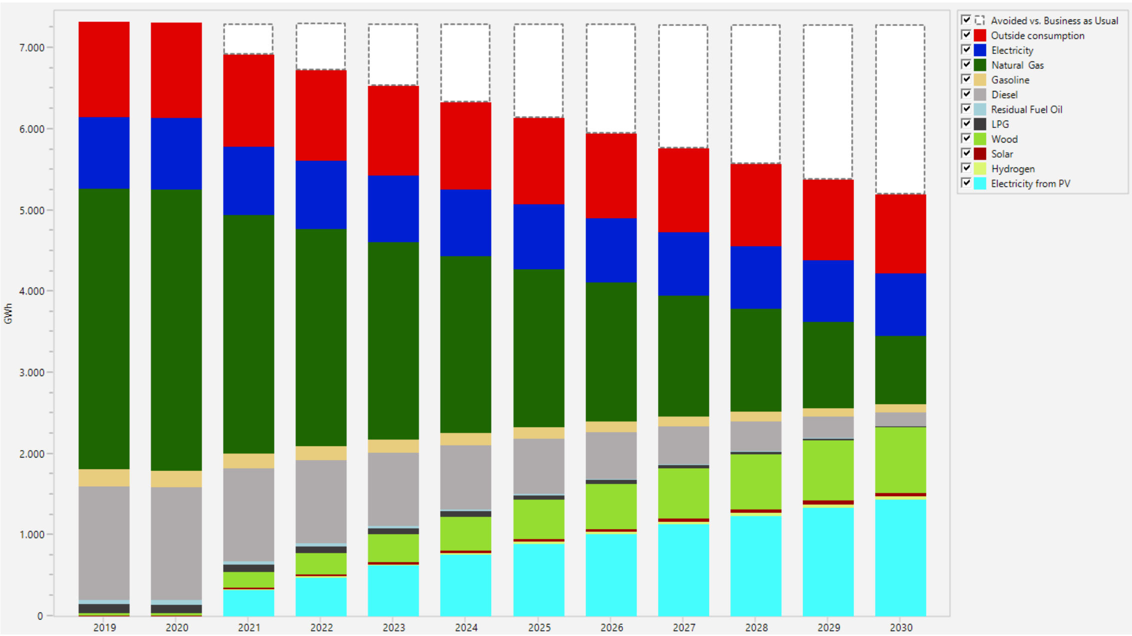

Figure 58. Matosinhos energy consumption by fuel in the Master scenario.

Next sections describe the assumptions and specific sectoral results of the Matosinhos Master scenario.

Residential buildings

According to the City Vision 90% of the Matosinhos' household stock is renovated by 2030. On this concern, a 50% energy saving (with regard existing buildings) has been considered for

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a full household renovation (including envelope renovation and substitution of heat systems), while a 80% reduction in energy use is considered for new households.

Table 35. Energy intensity (in MWh/person) by household type in Matosinhos Master scenario.

Household type	Energy intensity (MWh/person)
Existing households	2,73
Renovated households	1,37
New households	0,55

Table 36. Fuel mix by household type in Matosinhos Master scenario.

Household type	Fuel	Share
Existing households	Electricity	46,26%
	Natural gas	19,39%
	LPG	19,06%
	Diesel	13,33%
	Biomass	1,95%
	Solar thermal	0,001%
	Electricity from solar PV	0%[28]
Renovated households	Electricity	20%
	Natural gas	10%
	LPG	0%
	Diesel	0%
	Biomass	10%
	Solar thermal	20%
	Electricity from solar PV	40%
New households	Electricity	22%
	Natural gas	5%
	LPG	0%
	Diesel	0%
	Biomass	5%
	Solar thermal	25%
	Electricity from solar PV	43%

Along with the energy savings reached by the renovation of households (including envelope renovation and substitution of heating systems), the fuel mix of the sector is modified accordingly, achieving a considerable cut-down of GHG emissions within the sector thanks to a combination of heat electrification and renewables penetration.

Table 37. Starting and final fuel mix in the residential sector (excluding scope 3 consumption) in Matosinhos Master scenario.

	2019	2030
Electricity	46,26%	19,06%
Natural gas	19,39%	11,59%
Diesel	13,33%	2,38%
LPG	19,06%	3,40%

[28] Households which are not renovated still install PV systems until achieving a 31%/16% electricity from solar PV/electricity from the grid ratio.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 864374.

Biomass	1,95%	8,47%
Solar thermal	0,001%	16,52%
Electricity from solar PV	0%	38,04%

Finally, it should be noted that due to behavioural changes a 7,5% reduction in outside city-boundary consumption resulting from in-city residential activities has been considered by 2030.

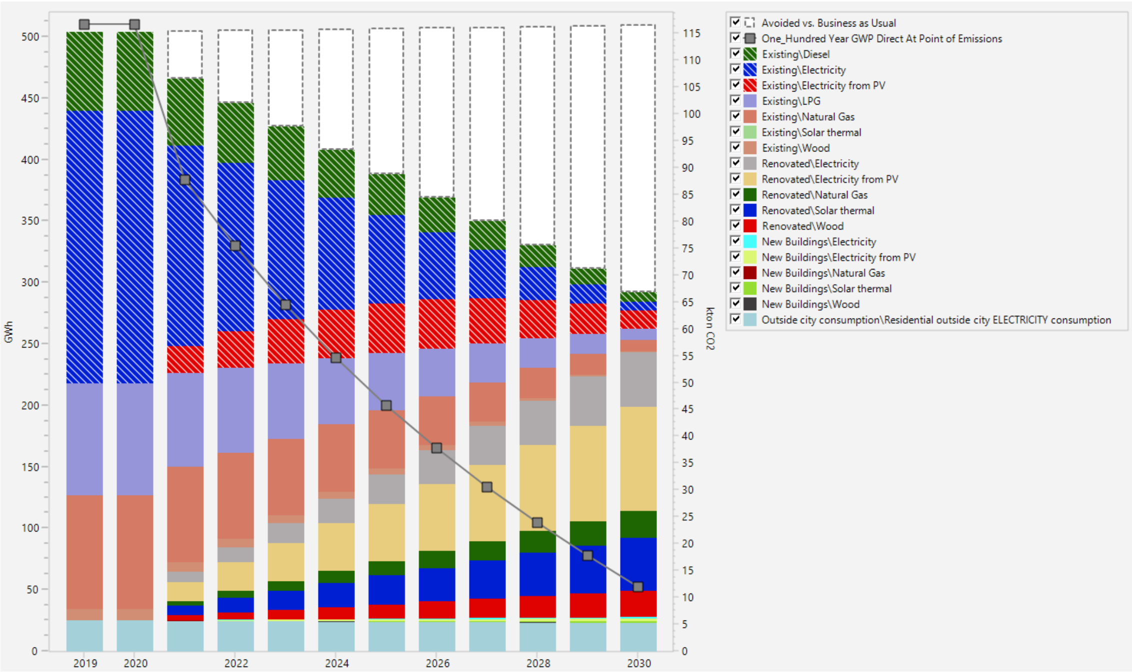

Figure 59. Residential energy consumption (by household type and fuel) and GHG emissions in Matosinhos Master scenario.

Private tertiary buildings

As for households, the City Vision assumes the renovation of 90% of the private tertiary buildings stock. Since the renovation of buildings considers the renovation of the building envelope as well as the renovation of heating systems, the sector is almost decarbonised thanks to the reduction of energy consumption and the use of cleaner fuels. No changes in energy/emissions occurring outside the city boundary as a result of in-city activities have been considered.

Table 38. Starting and final fuel mix in private tertiary buildings (excluding scope 3 consumption) in Matosinhos Master scenario.

	2019	2030
Electricity	67,08%	39,84%
Natural gas	19,13%	17,21%
Diesel	7,77%	0%
Residual fuel oil	1,66%	0%
LPG	1,73%	1,80%
Biomass	0,99%	1,57%
Solar thermal	1,64%	2,04%
Electricity from solar PV	0%	37,55%

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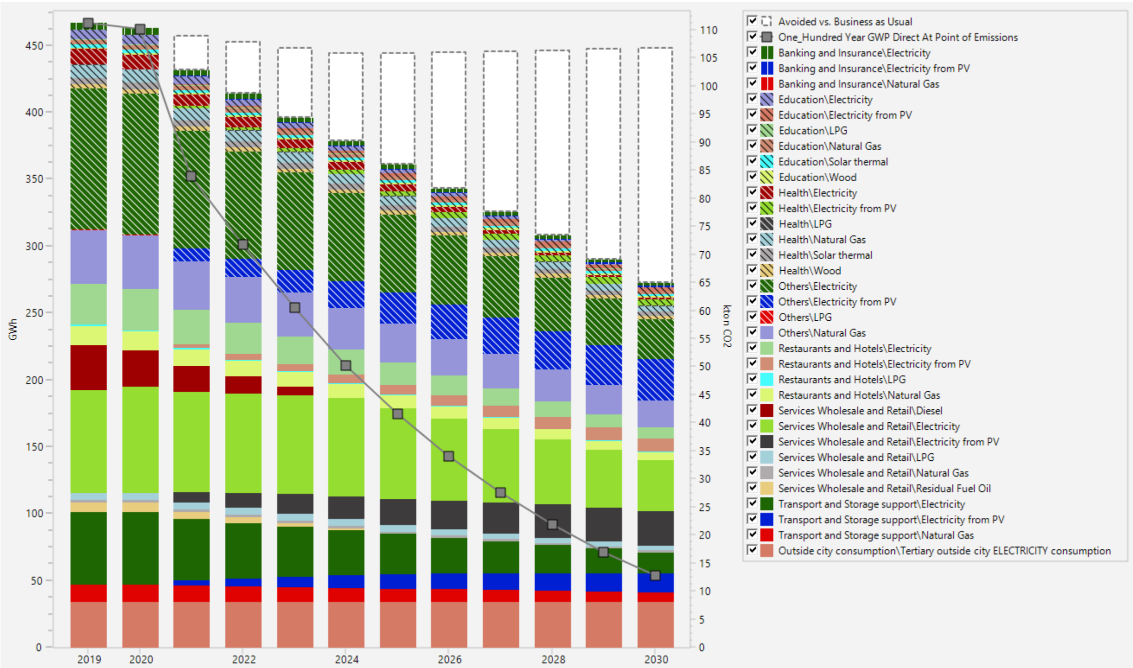

Figure 60. Private tertiary buildings energy consumption (by subsector and fuel) and GHG emissions in Matosinhos Master scenario.

Public administration buildings

As for the rest of the city's building stock, 90% of public administration buildings are renovated by 2030. Along with the energy reduction achieved through the renovation of buildings envelopes, public buildings support the almost full decarbonisation of the stock by phasing out natural gas and liquid fossil fuels and electrifying the heat demand. It should be noted that in this case, no changes in energy/emissions occurring outside the city boundary as a result of in-city activities have been considered neither.

Table 39. Starting and final fuel mix in public administration buildings (excluding scope 3 consumption) in Matosinhos Master scenario.

	2019	2030
Electricity	59,76%	47,53%
Natural gas	19,24%	0,19%
LPG	3,10%	0%
Biomass	6,76%	1,80%
Solar thermal	11,14%	2,96%
Electricity from solar PV	0%	47,52%

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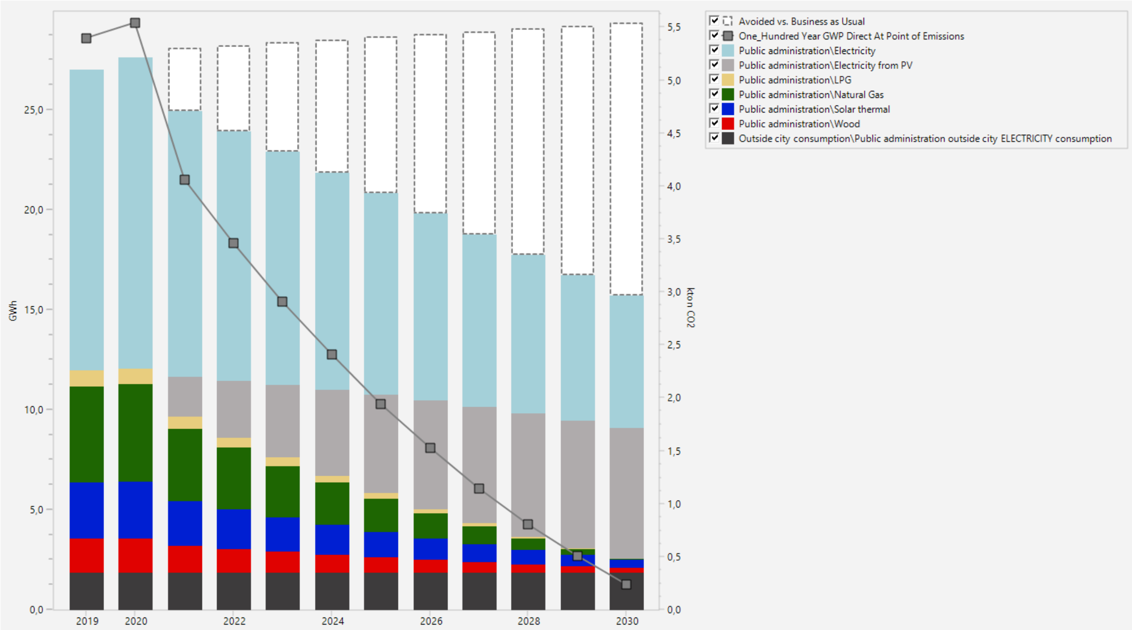

Figure 61. Public administration buildings energy consumption and GHG emissions in Matosinhos Master scenario.

Street lighting

Concerning street lighting it is assumed that the whole stock of street lamps is renovated with LED lamps by 2030.

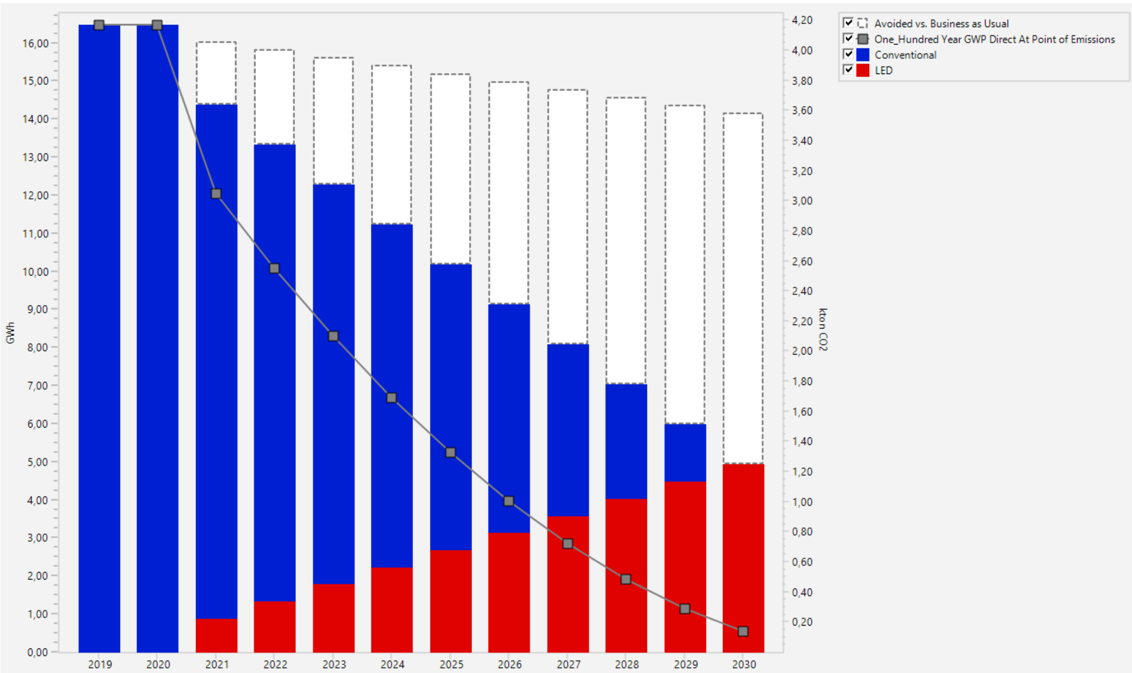

Figure 62. Street lighting energy consumption and GHG emissions in Matosinhos Master scenario.

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Industry

The industry sector is intended to reduce its energy use a 15% by 2030 thanks to efficiency measures. No changes in energy/emissions occurring outside the city boundary as a result of in-city activities have been considered.

Because of the increase of natural gas consumption reported with regard the previous version, initial fuel mix has changed and objective fuel mix has been adjusted. Therefore, It should be bear in mind that to fulfil this target mix, a drastic reduction of natural gas that is replaced by electricity technologies has been considered. On this concern, to meet the assumed energy reduction and 2030 fuel mix along with the emission reduction objective it has been necessary to consider that gas used in industrial applications is progressively blended with other fuels (biogas, H2…) (thus reducing its emission factor from 201,95 ton CO2/GWh to 149,66 ton CO2/GWh) to reach the emissions level set for 2030.

Table 40. Starting and final fuel mix in the industry sector (excluding scope 3 consumption) in Matosinhos Master scenario.

	2019	2030
Electricity	8,60%	13,24%
Natural gas	89,32%	24,96%
Diesel	0,13%	0%
Residual fuel oil	1,33%	0%
LPG	0,21%	0%
Biomass	0,40%	24,85%
Electricity from solar PV	0%	36,95%

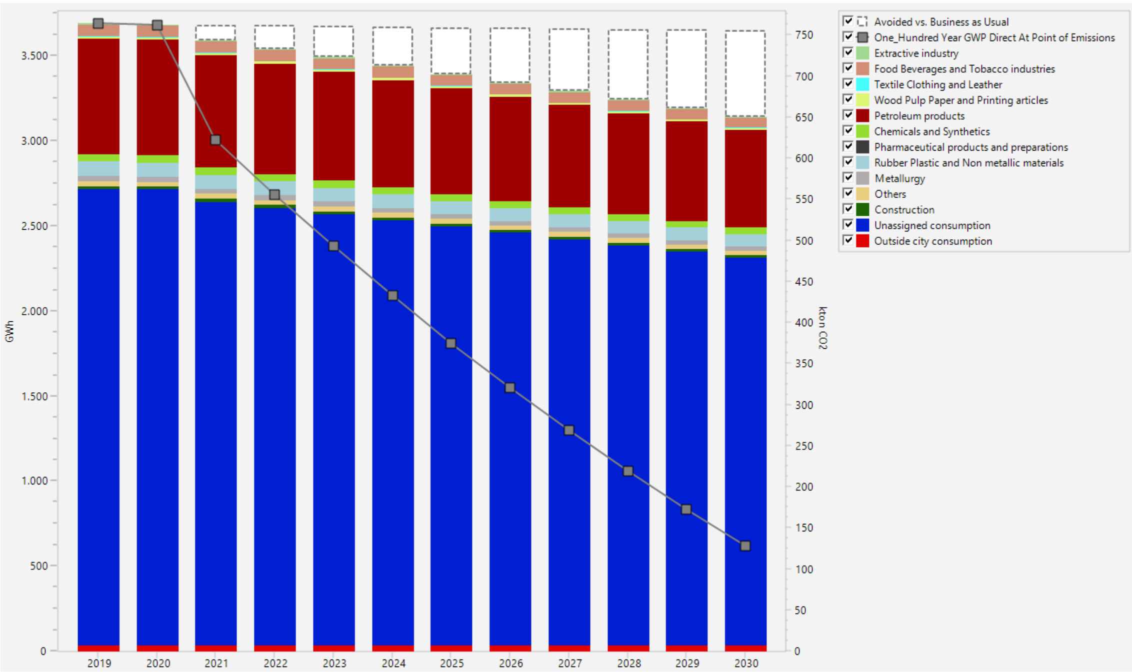

Figure 63. Industry energy consumption by subsector and GHG emissions in Matosinhos Master scenario.

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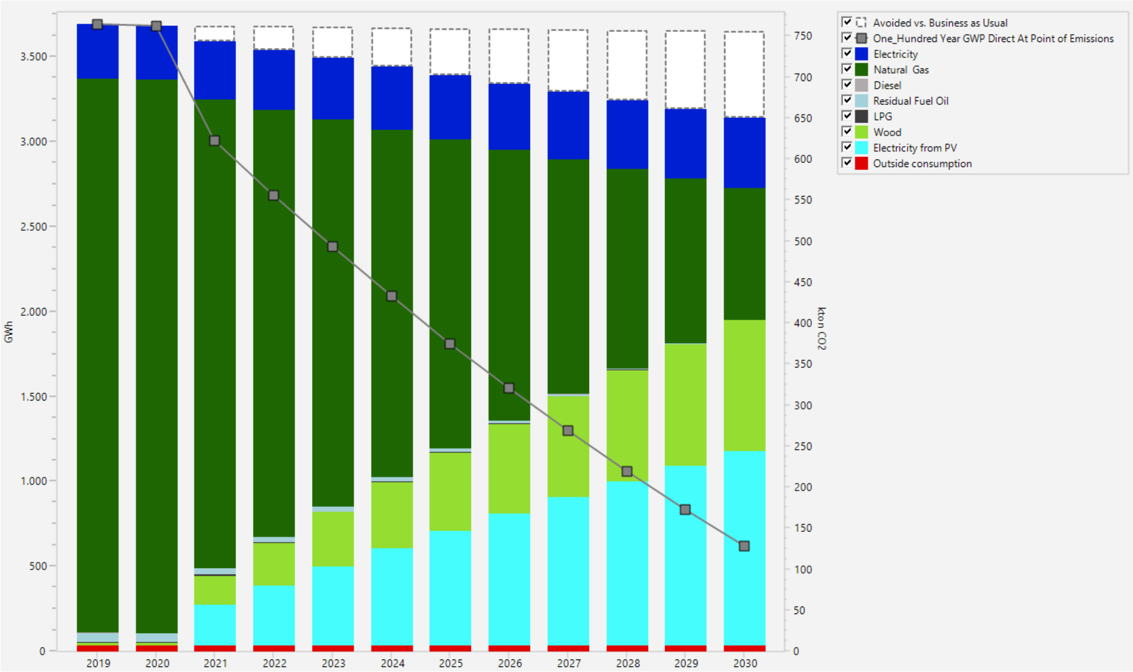

Figure 64. Industry energy consumption by fuel and GHG emissions in Matosinhos Master scenario.

Agriculture

In the agriculture sector, an overall 30% energy consumption reduction by 2030 is assumed through the implementation of energy efficiency measures. Cleaner fuels replace fossil fuels achieving the partial decarbonisation of the sector. No changes in energy/emissions occurring outside the city boundary as a result of in-city activities have been considered.

Table 41. Starting and final fuel mix in the agriculture sector (excluding scope 3 consumption) in Matosinhos Master scenario.

	2019	2030
Electricity	4,95%	10,72%
Natural gas	0,09%	0%
Diesel	94,96%	23,81%
Biomass	0%	4,76%
Electricity from solar PV	0%	60,71%

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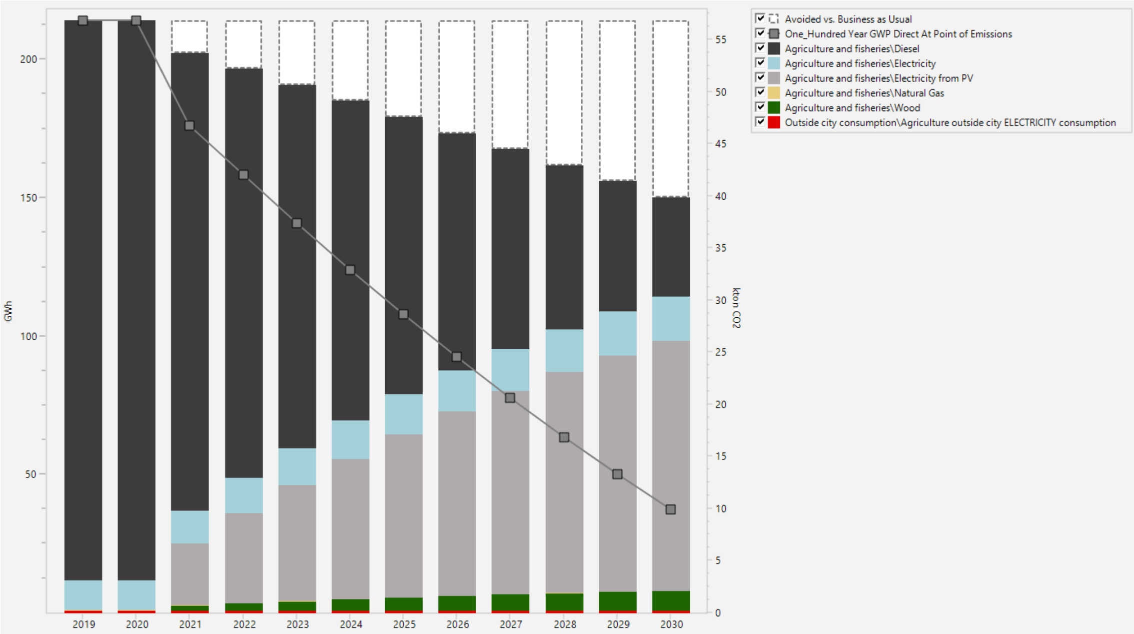

Figure 65. Agriculture energy consumption and GHG emissions in Matosinhos Master scenario.

Municipal fleet

Although it is considered that the stock of municipal vehicles increases 5% by 2030, the full electrification of the fleet by this date offsets the increase in energy and GHG emissions and achieves the almost total decarbonisation of the municipal fleet.

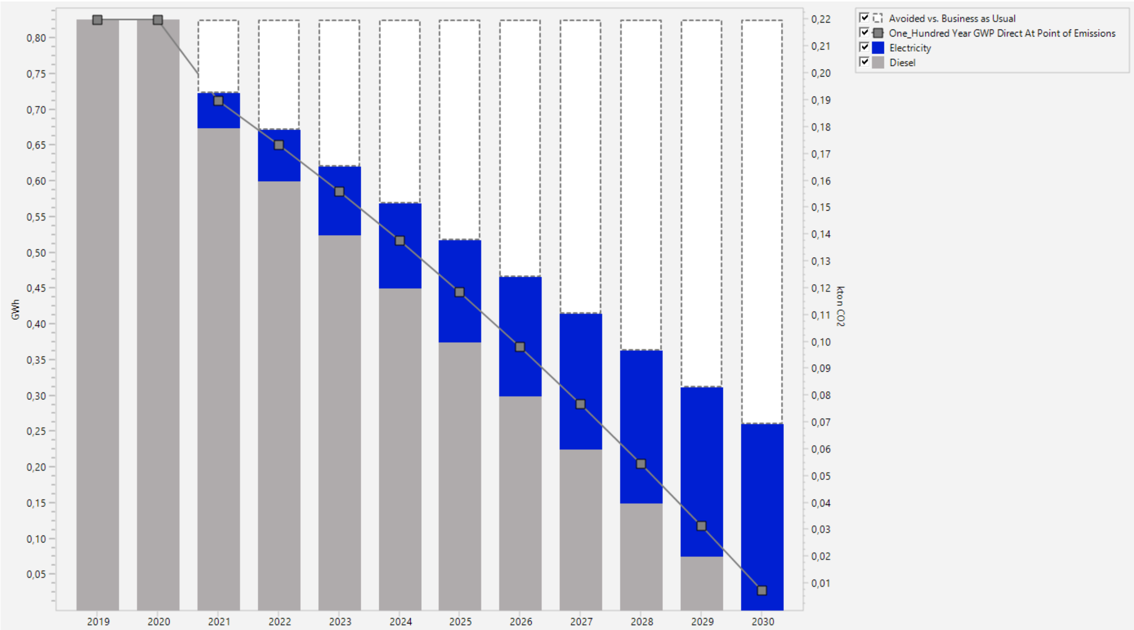

Figure 66. Municipal fleet energy consumption and GHG emissions in Matosinhos Master scenario.

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Public transport

On the one hand, rail and waterborne activity remains unchanged. On the other hand, the number of buses is assumed to be increased by 15% in 2030, assuming a shift from private transport towards this public transport mode. Concerning the bus stock mix, it has been considered that the whole bus fleet is electrified by 2030.

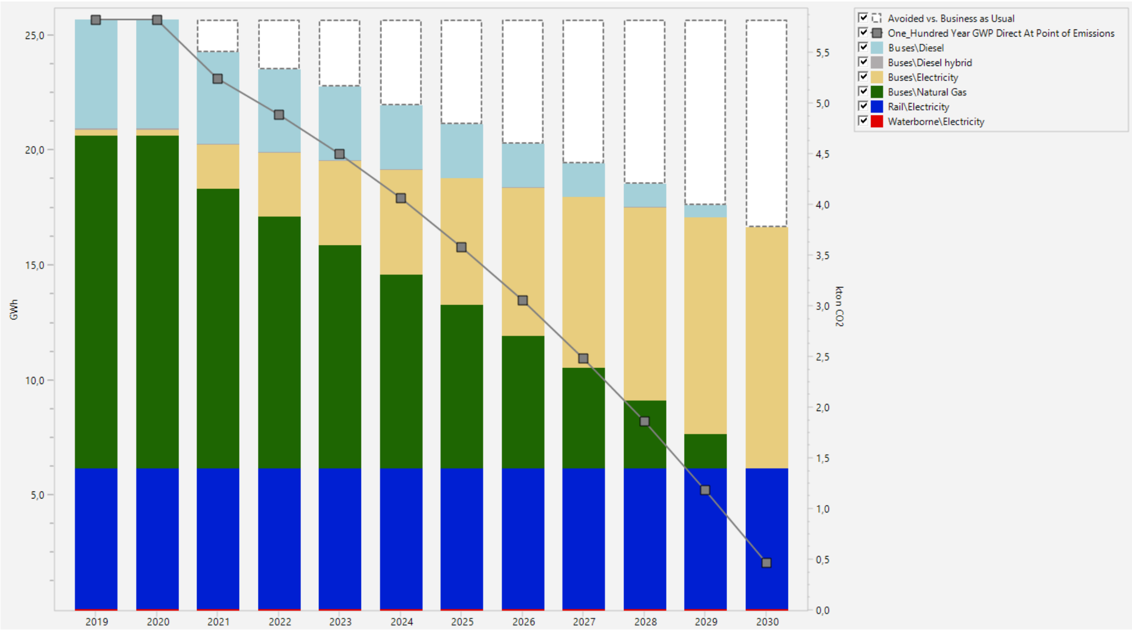

Figure 67. Public transport energy consumption and GHG emissions in Matosinhos Master scenario.

Private transport

The private transport sector characterisation has been improved with regard the previous version. Indeed, private transport fleet has been disaggregated by vehicle type based on national data and on the national ratio vehicle/person. Based on average fuel economies and mileages, an energy intensity (MWh/vehicle) has been defined for each type of vehicle, matching the overall reported energy consumption data of private transport.

Table 42. Matosinhos vehicle stock.

Vehicle type	Fuel	Nº vehicles	kWh/km	km/vehicle	MWh/vehicle
Two wheels	Gasoline	20156	0,41	2000	0,82
	Electricity	0	0,12	2000	0,25
Cars	Diesel	51910	0,72	9736	7,01
	Gasoline	38611	0,75	6271	4,70
	Gasoline (hybrid)	1131	0,60	6271	3,76
	Electricity	309	0,33	6271	1,07

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Light utility vehicles	Diesel	23504	1,03	20000	20,60
	Gasoline	274	1,07	15000	16,05
	Electricity	17	0,48	15000	3,65
Trucks	Diesel	1980	2,23	40000	89,20
	Electricity	0	0,67	40000	26,76
	Hydrogen	0	1,12	40000	44,60
Buses	Diesel	292	4,38	50000	219,00
	Electricity	0	1,31	50000	65,70
	Natural gas	10	14,8	50000	578,93

Regarding the Master scenario, the use of private transport is assumed to decrease. On this concern it is considered that the final outcome of the deployment of active mobility measures, the increase in the use of public transport, and other mobility measures (e.g. low emission zones, parking policies, car sharing…) is a 10% reduction of the vehicles registered within the city by 2030. In line with this hypothesis, and assuming that the deployed measures will have an impact on all the journeys within the city (i.e. internal journeys, inward journeys and outward journeys), it is assumed a 18% reduction in the energy/emissions occurring outside the city boundary as a result of in-city activities to meet the transport sector emission level set for 2030[29]. Along with the reduction of the private vehicle use, a switch between fuels used by the different vehicles has been considered.

Table 43. Fuel mix evolution by vehicle type in Matosinhos Master scenario.

		2019	2030
Two wheels	Gasoline	100%	0%
	Electricity	0%	100%
Cars	Diesel	56,45%	0%
	Gasoline	41,99%	0%
	Gasoline (hybrid)	1,23%	30%
	Electricity	0,34%	70%
Light utility vehicles	Diesel	98,78%	0%
	Gasoline	1,15%	30%
	Electricity	0,07%	70%
Trucks	Diesel	100%	0%
	Electricity	0%	50%
	Hydrogen	0%	50%
Buses	Diesel	96,63%	0%
	Electricity	0%	100%
	Natural gas	3,37%	0%

[29] On this concern, other hypotheses could be assumed to meet the 2030 emission target for the transport sector (e.g. additional mileage reduction, improvement of fuel economies, change in fuels consumed outside the city boundary as a result of in-city activities, etc…), but in the absence of further information the current use of diesel, gasoline, and LNG consumed outside the city boundary as a result of in-city activities has been directly reduced considering that the municipality has no jurisdiction or little leverage to act outside its borders (and that support and coordination with supra-municipal actors would be required to enact more specific and effective actions).

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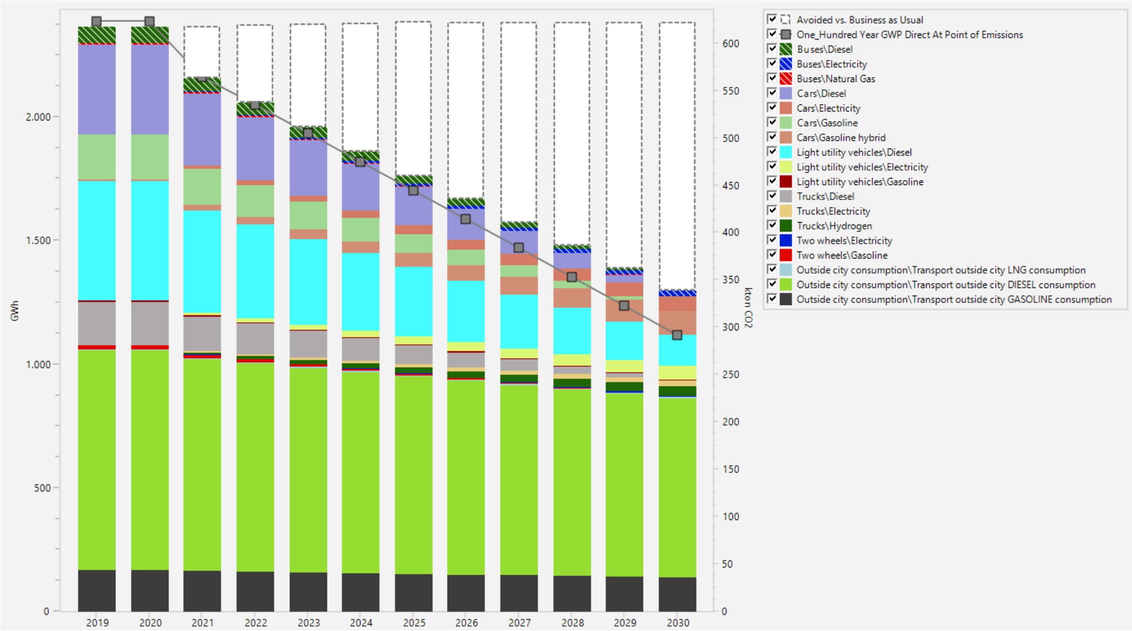

Figure 68. Private transport energy consumption (by type of vehicle and fuel) and GHG emissions in Matosinhos Master scenario.

Other sectors

Other sectors include waste and wastewater treatment, as well as non-energy related emissions. Regarding the former, a 50% reduction of solid waste and wastewater generation by 2030 has been considered. Hence reducing the energy required for their treatment. No fuel switches have been considered.

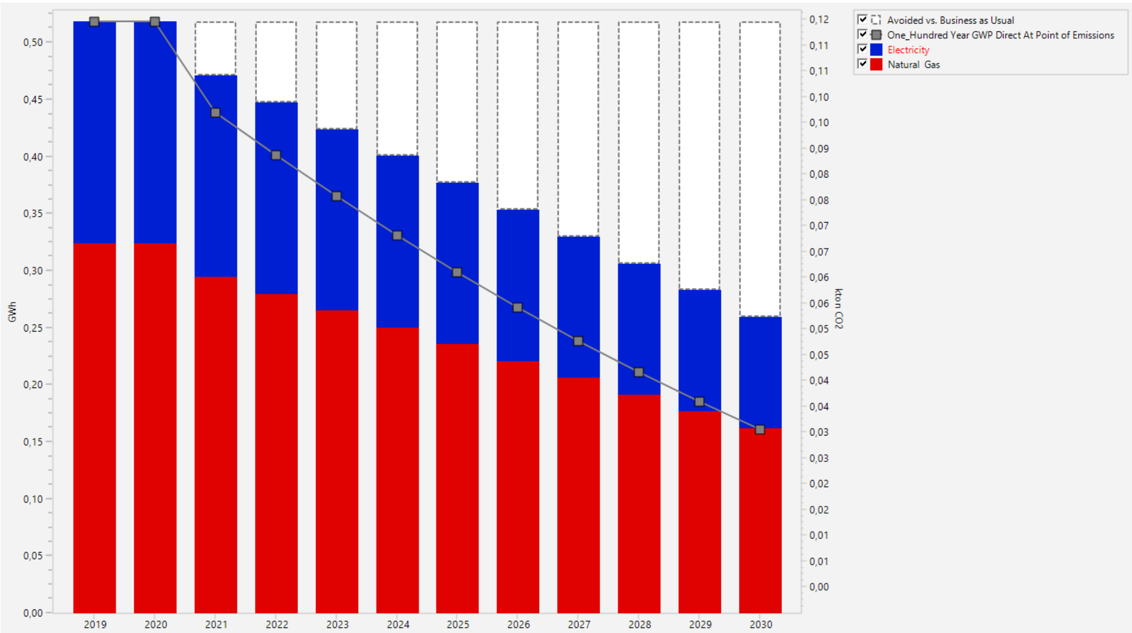

Figure 69. Solid waste treatment energy consumption and GHG emissions in Matosinhos Master scenario.

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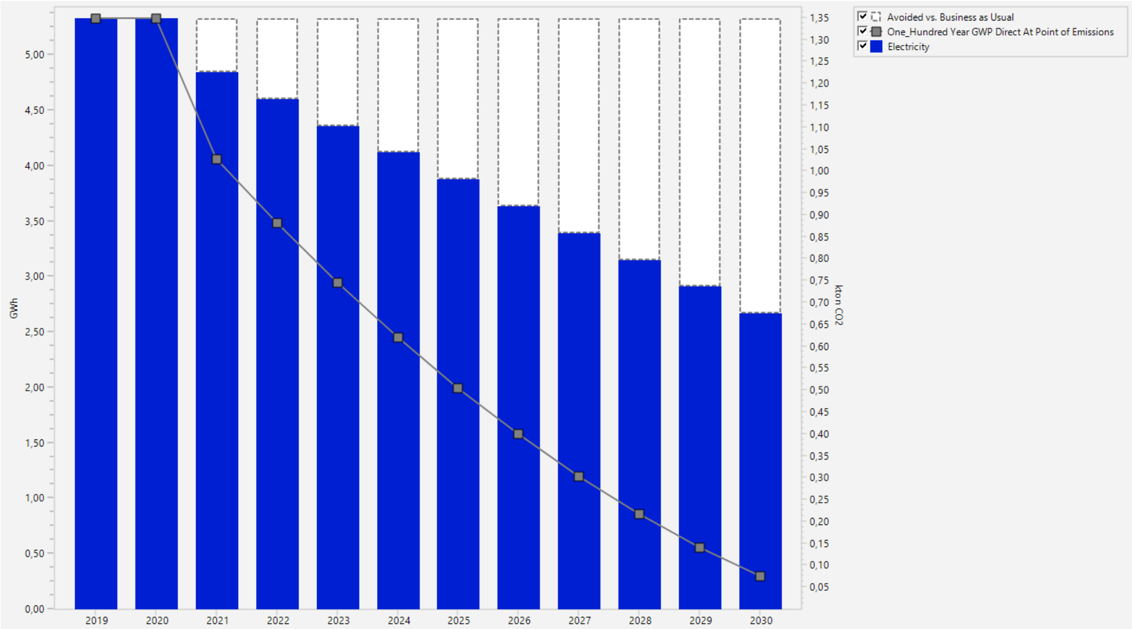

Figure 70. Wastewater treatment energy consumption and GHG emissions in Matosinhos Master scenario.

Non-energy related emissions gather: fugitive emissions (from the distribution of natural gas), waste emissions, IPPU, AFOLU, and carbon sequestration. In Matosinhos Master scenario emissions related to industrial processes, waste, and land use are reduced while carbon sinks are increased within the municipality.

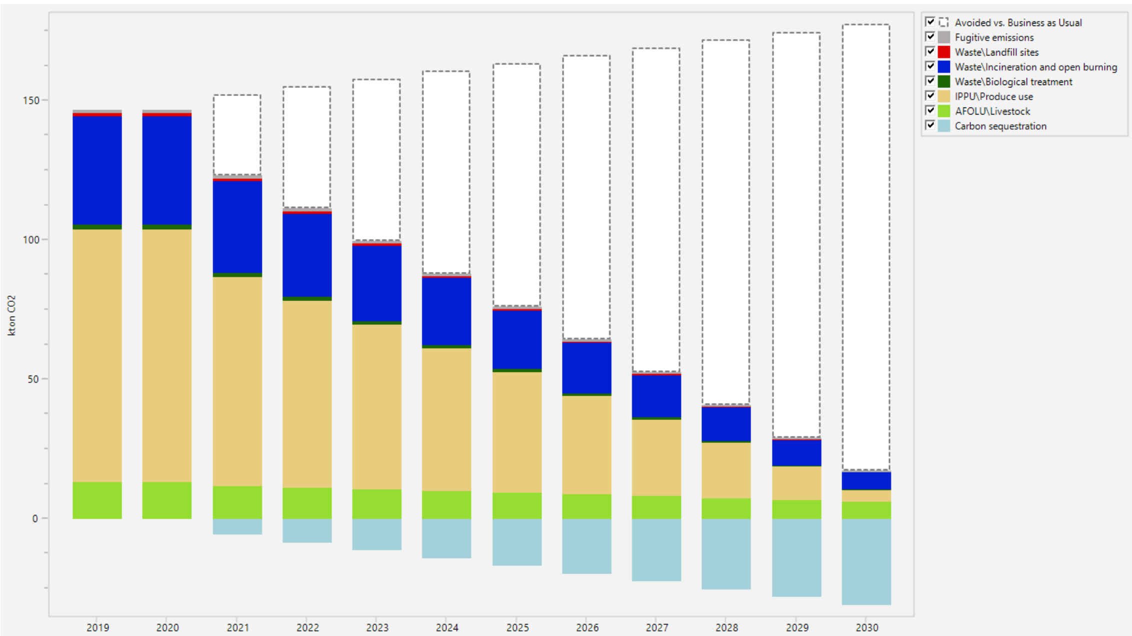

Figure 71. Evolution of non-energy related GHG emissions in Matosinhos Master scenario.

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Local energy generation

Matosinhos does not account for a DH network, therefore only electricity is produced within the city. As shown in Figure 72, The Master scenario envisages the increase in the consumption of electricity from solar PV in all end-use sectors. Assuming 1523 yearly working hours for this technology[30], 942 MW should be installed in the municipality to meet this consumption. Remaining electricity demanded in end-use sectors is imported from the national grid which by this 2030 is partially decarbonised.

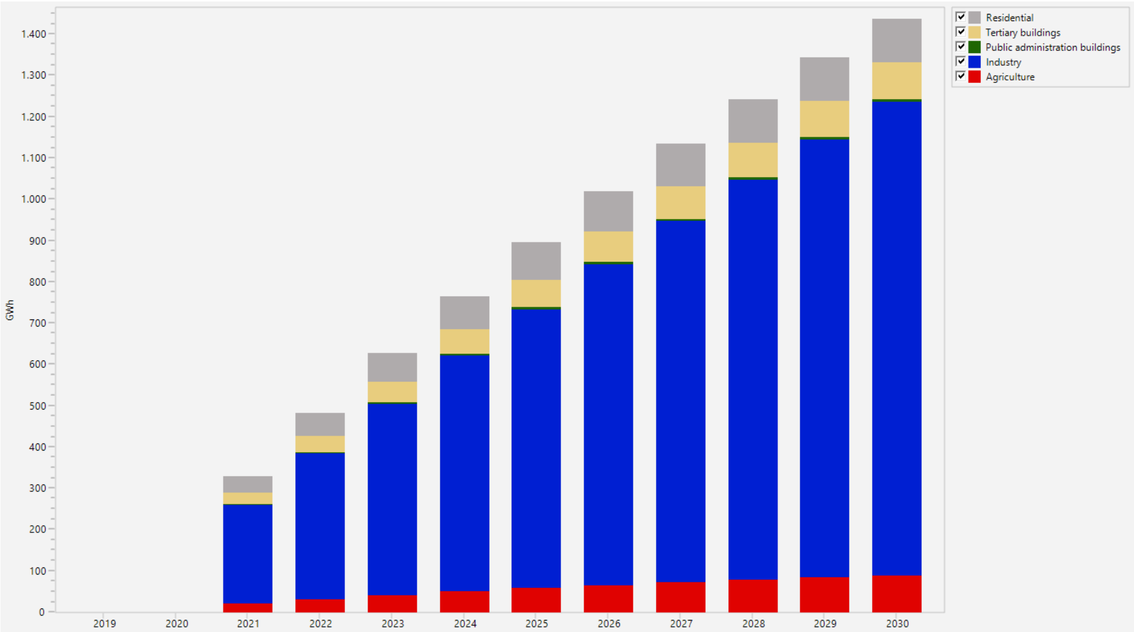

Figure 72. Evolution of electricity solar PV consumption in Matosinhos Master scenario.

4.7.4. The role of PED in City Vision

Since 2015, the year in which Matosinhos signed the mayors' pact, Covenant of Mayors, successive municipal executives have dedicated a considerable part of their municipal strategy to implement a set of initiatives in the field of energy and climate action that would develop a solid pathway to decarbonize the economy and to create a more sustainable future for the territory and its citizens.

The work carried out since then, especially in the last decade, allows the Municipality to aim for carbon neutrality in 2030, a reduction of 85% of the GHG Emissions compared to the reference year of 2009, anticipating the national goals when compared to the ambition defined in the Basis Climate Law (Lei de Bases do Clima), which points to carbon neutrality only in 2050. This anticipation is characterized by a structural and transversal change in how Matosinhos consumes and produces its energy, moves, lives and works. It implies major technological and behavioural change dependent on the commitment of all actors in the territory. It foresees a very competitive territory, a great degree of decentralization and digitalization of the National Electric System (SEN), a great circularity of the economy, a great diffusion of new forms of mobility (shared and soft ways) and an efficient consumption of all

[30] https://re.jrc.ec.europa.eu/pvg_tools/es/

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resources – energy, water and biological. Achieving this scenario requires a major implementation and financial effort, both public and private, in addition to considerable technological advances and simplification of regulatory and governance processes. Additionally, it will only be feasible through comprehensive civic participation.

In this sense, PED as a holistic innovative project becomes an important instrument for introducing a set of new technological solutions and concepts that would accelerate the energy transition, dedicated to a well-defined portion of the territory and to the infrastructures associated with it, seeking to create a sustainable and energy-independent ecosystem. From Matosinhos' perspective, the PED is an innovative urban planning and development concept that dedicates a greater effort to increasing the capacity of Renewable Energy Sources (RES) and addressing the energy poverty challenges, by considering specific and measurable actions:

1. Renewable Energy Integration: PEDs can incorporate renewable energy production systems such as solar panels, hydroelectric systems, and other clean energy technologies. This not only reduces the carbon footprint of the district but also contributes to the overall transition to a low-carbon energy system. It is foreseen the installation of 100 MWp of photovoltaic capacity in commercial buildings per decade until 2050, of which around 1200kWp will be installed in municipal infrastructures.

2. Energy Efficiency and Sustainability: PEDs prioritize energy efficiency through the integration of renewable energy sources, energy-efficient technologies, and sustainable design principles. It is foreseen the installation of 490 kWp of photovoltaic capacity in social housing neighbourhoods, a deep rehabilitation (insulation of facades and roofs, replacement of glazed openings, etc.) of the overall 674 dwellings in the existing social municipal buildings and the substitution of large electrical equipment with others with greater efficiency (energy class A+ or higher) in all municipal dwellings with potential savings of 14.2 GWh, are some of the measures that will contribute to a more environmentally friendly and resource-efficient urban development.

3. Smart Grids and Infrastructure: Smart grids are often implemented in PEDs to optimize energy distribution and consumption. It is expected to broadly install smart electricity and natural gas metering infrastructures with the aim of informing consumers, in real-time, about usage patterns and inducing effective behavioural changes and at the same time unlock mechanisms to enable efficient management of energy resources, that can support the integration of decentralized energy sources, and enhance overall energy resilience.

4. Urban Planning and Design Innovation: PEDs often involve innovative urban planning and design that prioritize walkability, green spaces, and sustainable architecture. This approach creates a more liveable and attractive urban environment for residents.

5. Community Engagement and Well-being: PEDs emphasize community engagement in the planning and development process. Inclusivity and participation from local residents contribute to a sense of ownership and well-being, fostering a strong community fabric.

6. Economic Development: The development of PEDs can stimulate economic growth by attracting investments in clean energy technologies, creating job opportunities, and fostering innovation. This economic development contributes to the overall prosperity of the city.

7. Cultural and Educational Impact: PEDs have in important role on finding effective communication channels to promote good practices in energy use, which allows changes in

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consumption patterns and the adoption of more rational behaviours in energy consumption. This strategy can be developed through initiatives promoted at the school level, but also among the general population through cultural events, educational programs, and public awareness campaigns.

Overall, the Matosinhos Positive Energy District shall serve as an experimental case of developing renewable energy sources and addressing energy poverty by promoting clean energy technologies, fostering community engagement and ensuring the equitable distribution of benefits. As models for sustainable urban development, Matosinhos aims to demonstrate how innovative and community-driven approaches can positively impact both the environment and the well-being of residents/citizens.

4.8. Riga

4.8.1. Process followed for city vision development

In order to facilitate the city vision co-development process, in 2020 the city of Riga established the Smart City Planning Group (SCPG). It was done within the ATELIER project, following the *Cities4ZERO* methodology. SCPG is actively working until now and is being periodically updated.

Riga SECAP-2030

As part of ATELIER project, during 2021 Riga elaborated the “Riga Sustainable Energy and Climate Action Plan 2022-2030” (further – Riga SECAP-2030) – an ambitious, goal-oriented, integrated policy framework for a smart urban decarbonisation transition, inspired by the *Cities4ZERO* methodology, applied in ATELIER.

Development process of Riga SECAP-2030 depicts a strategic, participatory and multi-sectorial energy planning approach based on a long-term system thinking, bringing SCPG stakeholders together to achieve a common vision for future urban decarbonisation strategies, mutually agreed targets, priority areas and appropriate measures.

Co-development of Riga SECAP-2030 was accomplished in a joint effort by building common vision, creating a consensus, mobilising joint actions, shaping the city’s development path as well as promoting a sense of ownership and commitment among the involved stakeholders – SCPG – towards the achievement of the common goals.

Thanks to the active involvement of SCPG, **Riga SECAP-2030 was one of the most discussed energy and climate action plans** in Latvia and beyond. Within the development of Riga SECAP-2030, **SCPG conducted 18 working group meetings** in smaller and larger formations, **involving more than 280 specialists and experts** of various fields representing municipal departments and municipal services providers, academia, research, advisory, sectorial associations, NGO’s and active civil society.

In April 2022 Riga SECAP-2030 was approved by Riga City Council.

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Riga CCC

One of the lessons learnt during the elaboration of Riga SECAP-2030 was that decarbonising a city involves a complex strategic planning and requires a system thinking. Set climate goals can only be achieved by an efficient cross-sectoral collaboration and deployment of cross-sectorial innovations in all related areas, from energy production, distribution and efficient use, clean and sustainable mobility, smart and climate-neutral buildings, circularity in all sectors of economy, to education and behavioural change of each citizen, as climate-neutral cities are made by responsible residents.

With this in mind, in March 2023 **within the framework of "100 Smart and Climate-Neutral Cities" mission**, **the City of Riga launched the elaboration of a Riga Climate City Contract** (Riga CCC).

CCC is a governance innovation tool to address the challenges and barriers to reaching climate neutrality by 2030. CCC is the documented result of an iterative co-creation process. The CCC is one process and document with three interlinked components: Commitments, Actions, and Investments.

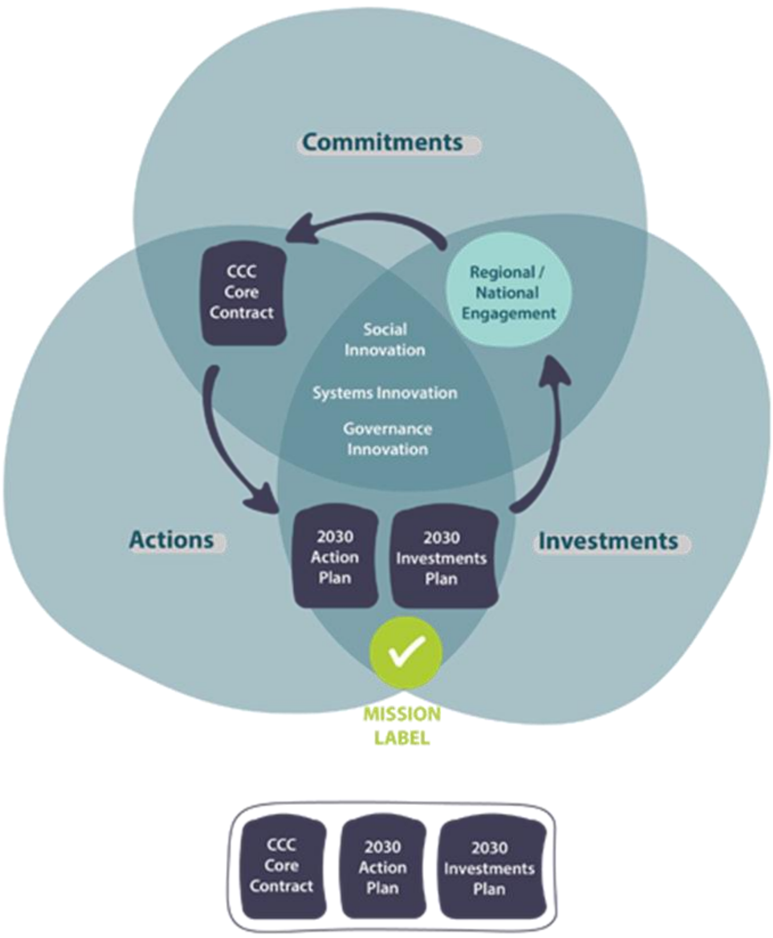

Figure 73. CCC Development Process in the City of Riga

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City vision co-development process: methodology applied in the City of Riga

Taking into consideration the scope of CCC, in summer 2023 the city of Riga organized a marketing campaign and received applications from 72 external stakeholders willing to collaborate with the city on CCC development. In result, the SCPG in Riga was considerably enlarged, involving in SCPG's work also the CCC stakeholders from National government institutions, as well as from the private sector, e.g., industry, energy producers and suppliers, financial institutions, SMEs, innovation think tanks, and many other stakeholders who expressed their will to take part in Riga CCC development.

The city vision co-development process in Riga is implemented through face-to-face meetings of enlarged SCPG. The key role of the SCPG is related to leveraging feedback to co-develop Riga's city vision – climate goals, transition pathways and policy scenarios towards climate neutrality, namely the Riga SECAP-2030 scenario and Climate-Neutral Riga 2030 scenario.

This is (being) done through numerous **face-to-face meetings** with key local stakeholders from the (enlarged) SCPG within the sectorial expert working groups, in the following sequential co-creation process:

1. **June 2023. Launch and introduction: Climate goals of Riga and CCC process**

Thematic focus: assumptions for each sector and scenario analysis (Riga SECAP-2030 scenario vs. Climate-Neutral Riga 2030 scenario). Assessment on the emissions' reduction expected at EU, National and Riga city level. CCC development process and ecosystem of CCC stakeholders.

2. **July - September 2023. Round of internal consultations**

Thematic focus: internal consultations among Riga municipal departments, municipal services providers on the city vision and the CCC development. Review of the city' strengths and opportunities, assessment of challenges and barriers in Riga SECAP-2030 implementation. Identification of municipal needs, potential measures and next steps to reach net zero.

3. **September - December 2023. Build and refine pathways and scenarios**

Thematic focus: co-creation process addressing all CCC sectors in various consecutive sectorial SCPG working sessions (transport, buildings, industry, energy and consumption, waste, land use). Understanding the measures and how the measures contribute to reach net zero; how to fill the "gap" between two scenarios, what is covered and what is not covered? Local experts from each sector presenting top-down needs for the sector, during each sectorial session, top down and bottom-up approaches are reconciliated.

4. **January 2024. Political validation**

Thematic focus: climate goals, adopted pathways and preferred policy scenario must be politically assumed and recognized by SCPG stakeholders, as well as policymakers. This political validation may imply the need to adapt/adjust/finetune the pathways proposed during the co-creation process.

5. **February 2024. Commitment**

Thematic focus: Public presentation of the Riga City Vision: adopted transition pathways and preferred policy scenario already assumed by decision-makers and stakeholders as politically

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binding planning instrument to be inserted into the development of Riga CCC and/or update of Riga SECAP-2030.

6. **March 2024. Submission of Riga CCC to the European Commission**

Riga CCC submitted for validation by the EC to receive the "Mission Label", a quality assurance certification that is envisioned to unlock synergies with other EU funding programmes and other funding and financing resources.

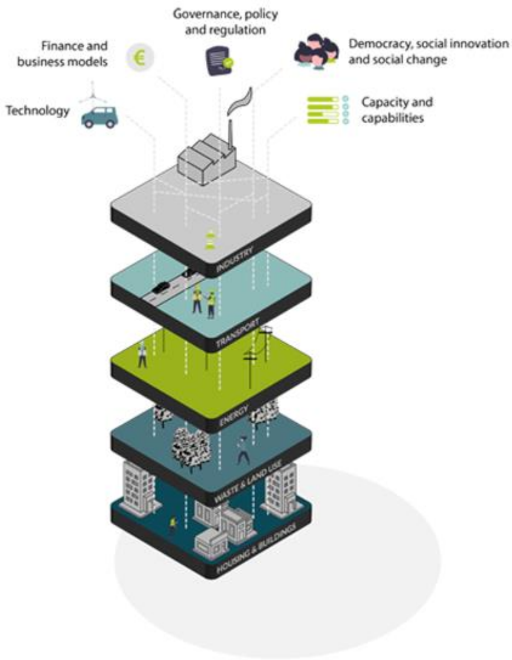

Figure 74. Ecosystem of CCC Stakeholders in the City of Riga

4.8.2. City Vision

Riga SECAP-2030: a climate neutral municipality by 2030

By adopting Riga SECAP-2030 the Riga City Municipality has committed to becoming a climate neutral municipality by 2030, ensuring that municipal institutions are as sustainable as possible with the least impact on the climate and municipal infrastructure and being resilient to the risks caused by climate change. The vision of a climate-neutral and resilient municipality includes such goals as a gradual shift from private cars to more sustainable transport modes, significant improvements in the field of waste management, ensuring sustainability of city's nature capital, achieving better environmental quality, shift to circular economy model, and many other measures.

The key goals of Riga SECAP-2030 have been set, following the EU and National energy and climate objectives. Specific goals of Riga SECAP-2030 are related **to the city vision of a climate-neutral and resilient municipality by 2030** and include the following measurable targets to be achieved by 2030:

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- Climate-neutral municipal buildings using 100% RES as the heat energy source,
- Decrease of energy consumption in municipal buildings – 20% reduction compared to 2019,
- Decrease energy consumption in centralised district heating – 20% reduction compared to 2019,
- Comprehensive energy renovation of multi-apartment residential housing – 2.000 buildings refurbished,
- Climate-neutral municipal lighting and traffic lights infrastructure using 100% RES,
- Climate-neutral municipal transportation fleet: zero-emission vehicles using 100% RES, and other targets.

Climate-Neutral Riga 2030: net zero city

Information in progress.

4.8.3. Alternative scenarios

In line with what has been described in the previous sections, the city of Riga was interested in the modelling of two scenarios with a 2030 horizon. On the one hand a scenario including the current SECAP measures and their impact on the city energy consumption and GHG emissions. On the other hand, a scenario aiming for a climate neutral city by 2030 in the context of Riga CCC., and take into account the city's starting point and baseline trends while modelling specific measures, actions and policies depending on the scenario.

Table 44. Achieved energy savings in Riga scenarios.

SECTOR	2019[31] (GWh)	SECAP scenario 2030 % reduction with regard 2019	Riga Carbon Neutral scenario 2030 % reduction with regard 2019
Residential	3.585	-15%	-65%
Private tertiary buildings	2.077	-7%	-40%
Municipal buildings	308	-20%	-50%
Street lighting	30	-72%	-72%
Water supply and sewage system	35	-20%	-50%
Industry	1.633	+16%	+0%
Municipal fleet	17	-81%	-81%
Public transport	211	-30%	-62%
Private transport	3.031	-25%	-54%
TOTAL	**10.928**	**-13%**	**-47%**

[31] Base year used in the model has been changed with regard the BaU version in D2.5. In line with the reference used in the city SECAP document new base year is 2019. Moreover, 2020 has been also calibrated with historical data. Nevertheless, data should be revised since inconsistencies are still found. The breakdown of data by sector and fuel has been difficult in some cases and has been performed based on assumptions or skewed data.

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Regarding GHG emissions different assumptions have been considered. On the one hand, the SECAP scenario only considers a partial decarbonisation of the local electricity supply (mainly due to the decarbonisation of the national grid), whereas impact of local heat is halfed down due to the penetration of RES in local heat generation plants (see section 0). On the other hand, the full decarbonisation of both power and heat networks are assumed in the Riga Carbon Neutral scenario in order to fulfil the carbon neutrality target. However, it should be noted that to achieve this objective, around 300 kton CO_2 (from remaining fossil-fuelled vehicles in the private transport sector) should be compensated.

Table 45. Considered emission factors for electricity and heat from DH in Riga scenarios.

FUEL	2019	SECAP scenario (2030)	Riga Carbon Neutral scenario (2030)
Electricity (ton CO2/MWh)	0,109	0,070	0
Heat (DH) (ton CO2/MWh)	0,130	0,072	0

Table 46. Achieved GHG[32] savings in Riga scenarios.

SECTOR	2019 (kton CO2)	SECAP scenario 2030 % reduction with regard 2019	Riga Carbon Neutral scenario 2030 % reduction with regard 2019
Residential	450	-47%	-100%
Private tertiary buildings	285	-19%	-100%
Municipal buildings	39	-100%	-100%
Street lighting	3	-100%	-100%
Water supply and sewage system	4	-100%	-100%
Industry	151	-1%	-100%
Municipal fleet	5	-100%	-100%
Public transport	46	-54%	-100%
Private transport	747	-26%	-60%
TOTAL	**1.730**	**-31%**	**-83%**

[32] Note that GHG emissions in all figures and tables for Riga scenarios reflect a scope 2 assessment. That is, power and heat generation emissions are allocated to the final energy consumption of electricity and heat in end-use sectors.

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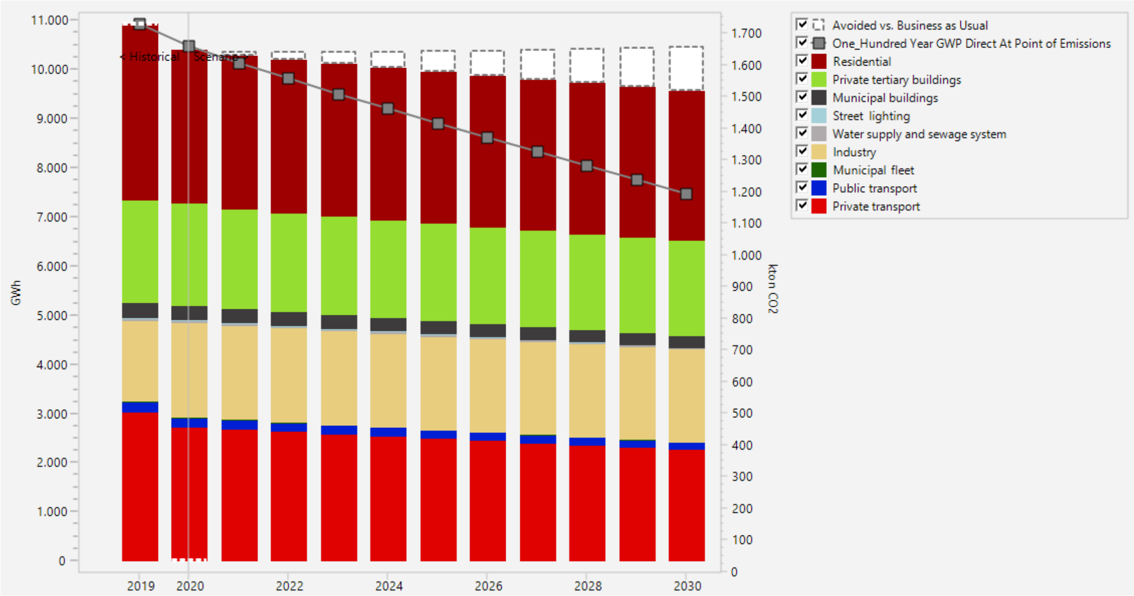

Figure 75. Riga energy consumption and GHG emissions by sector in the SECAP scenario.

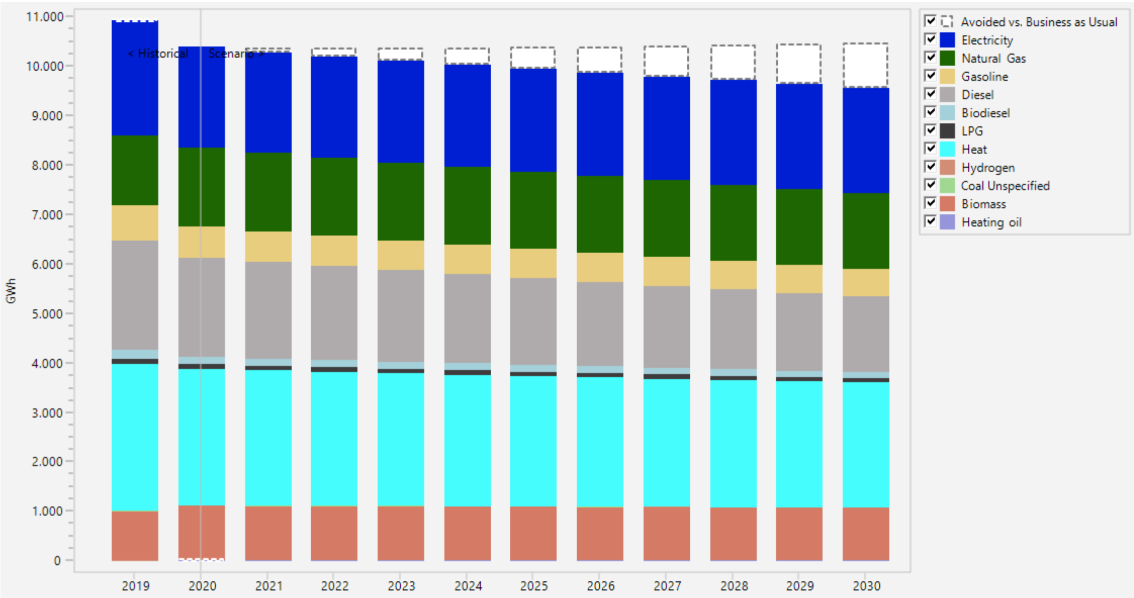

Figure 76. Riga energy consumption by fuel in the SECAP scenario.

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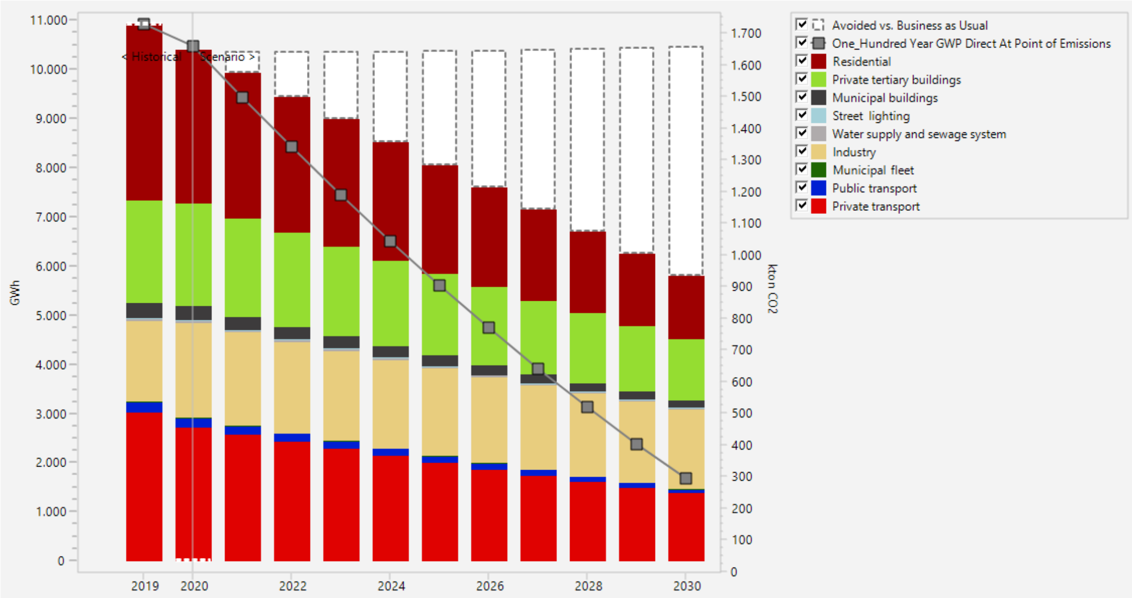

Figure 77. Riga energy consumption and GHG emissions by sector in the Riga Carbon Neutral scenario.

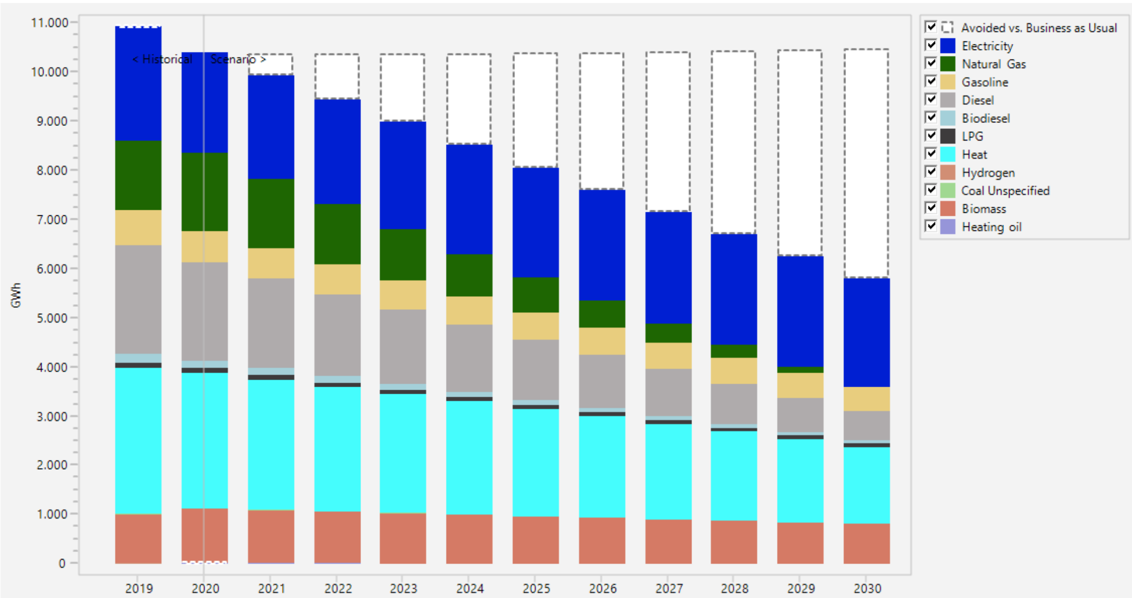

Figure 78. Riga energy consumption by fuel in the Riga Carbon Neutral scenario.

Next sections describe the assumptions and specific sectoral results of the SECAP and Riga Carbon Neutral scenarios.

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Residential buildings

SECAP scenario considers the renovation of 2000 apartment buildings (which represents around 10% of the residential building stock) by 2030[33], while the full stock is considered to be renovated by this year in the Riga Carbon Neutral scenario. Regarding achieved savings by the renovation of households, in the Riga SECAP scenario a 45% energy reduction with regard existing buildings has been considered for a full household renovation (including envelope renovation and substitution of heating systems), while new households are assumed to use 75% less energy than existing ones. In the Carbon Neutral scenario these values are improved reaching energy reductions of 60% and 90% for renovated and new households respectively. The same construction rate of new households as in the BaU has been considered in both scenarios.

Table 47. Energy intensity (in kWh/m²) by household type in Riga scenarios.

<table>
<tr><th></th><th>2019</th><th>SECAP scenario</th><th>Riga Carbon Neutral scenario</th></tr>
<tr><td>Existing households</td><td>179,55</td><td colspan="2">154,94</td></tr>
<tr><td>Renovated households</td><td>98,75</td><td>85,22</td><td>61,97</td></tr>
<tr><td>New households</td><td>44,89</td><td>38,73</td><td>15,49</td></tr>
</table>

Along with the energy savings reached by the renovation of households (including envelope renovation and substitution of heating systems), the fuel mix of the sector is modified accordingly depending on the scenario. It should be noted that existing households that do not renovate their envelope are considered to partially renew their energy systems, replacing their fossil-based heating systems (mainly natural gas and coal) by DH and electric heating systems. Altogether, Riga residential building stock is only fully decarbonised in the Carbon Neutral scenario thanks to the combination of envelope and heating systems renovation and the full decarbonisation of both heat and power networks.

Table 48. Fuel mix by household type in Riga scenarios.

<table>
<tr><th></th><th></th><th>2019</th><th>SECAP scenario (2030)</th><th>Riga Carbon Neutral scenario (2030)</th></tr>
<tr><td rowspan="5">Existing households</td><td>Electricity</td><td>14,08%</td><td colspan="2">19,63%</td></tr>
<tr><td>DH</td><td>62,65%</td><td colspan="2">65,36%</td></tr>
<tr><td>Natural gas</td><td>12,79%</td><td colspan="2">8,54%</td></tr>
<tr><td>Coal</td><td>0,79%</td><td colspan="2">0%</td></tr>
<tr><td>Biomass</td><td>9,69%</td><td colspan="2">6,47%</td></tr>
<tr><td rowspan="3">Renovated households</td><td>Electricity</td><td>-</td><td>22,64%</td><td>34,64%</td></tr>
<tr><td>DH</td><td>-</td><td>65,36%</td><td>65,36%</td></tr>
<tr><td>Natural gas</td><td>-</td><td>12%</td><td>0%</td></tr>
<tr><td rowspan="3">New households</td><td>Electricity</td><td>-</td><td colspan="2">34,64%</td></tr>
<tr><td>DH</td><td>-</td><td colspan="2">65,36%</td></tr>
<tr><td>Natural gas</td><td>-</td><td colspan="2">0%</td></tr>
</table>

[33] It should be noted that a similar rate was already considered for the BaU scenario, therefore almost no differences can be observed between both scenarios.

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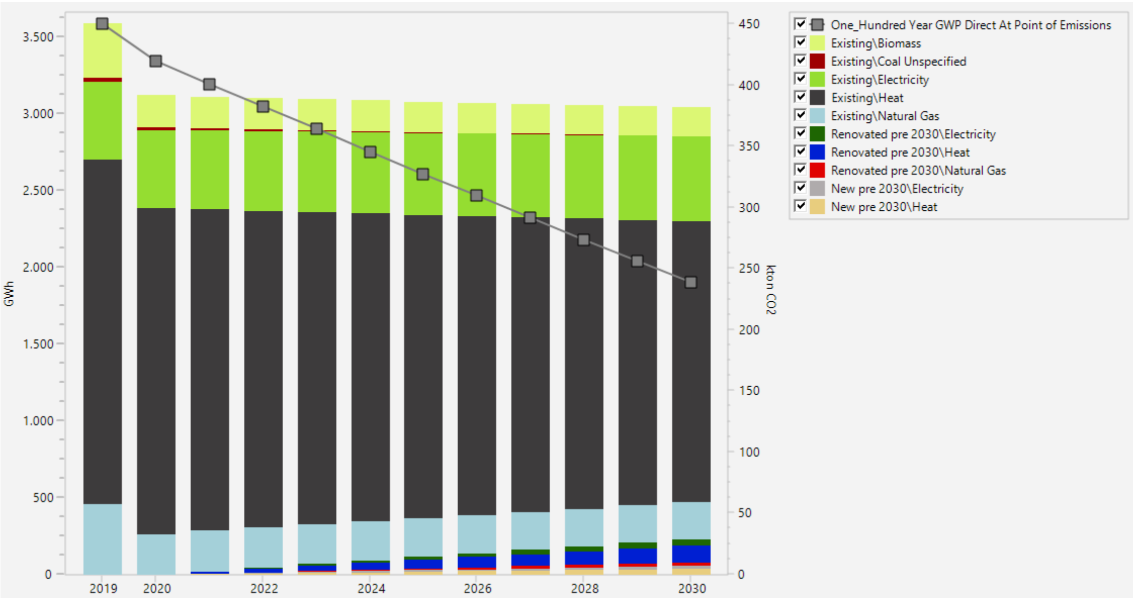

Figure 79. Residential energy consumption (by household type and fuel) and GHG emissions in Riga SECAP scenario.

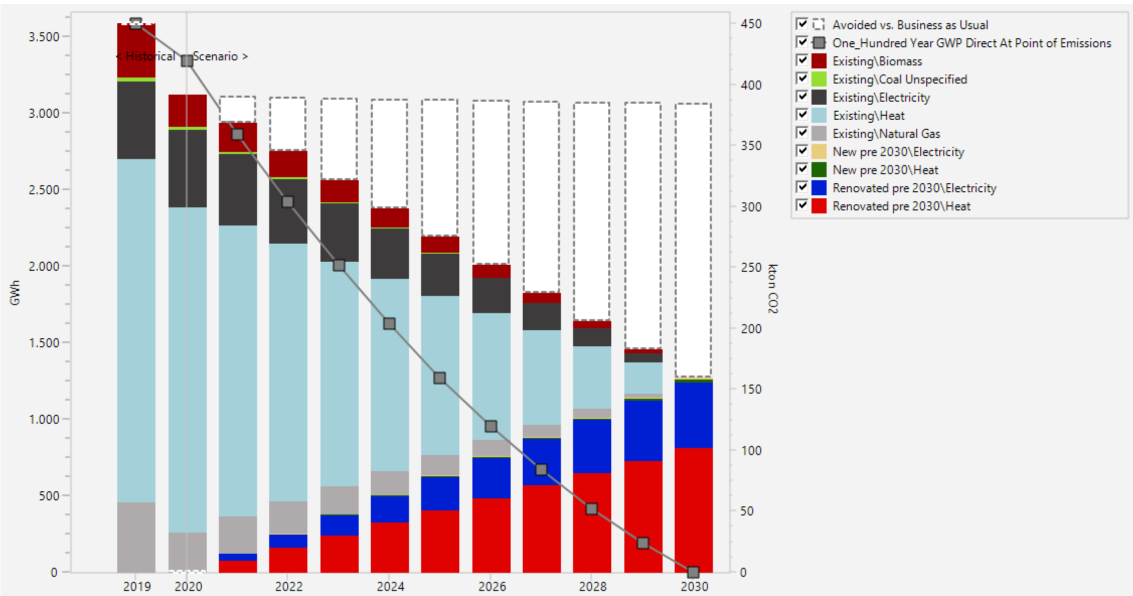

Figure 80. Residential energy consumption (by household type and fuel) and GHG emissions in Riga Carbon Neutral scenario.

Private tertiary buildings

The city of Riga had no objectives nor measures set for the private tertiary sector in its SECAP. Therefore, the SECAP scenario has not contemplated any actions within this sector than the ones already assumed for the BaU scenario (and therefore no differences with regard this scenario can be observed). The Carbon Neutral scenario assumes however a 40% energy

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reduction with regard the base year due to a bolder implementation of energy efficiency measures. Natural gas is completely removed in this scenario, achieving the full decarbonisation of the sector.

Table 49. Starting and final fuel mix in private tertiary buildings in Riga scenarios.

	2019	SECAP scenario (2030)	Riga Carbon Neutral scenario (2030)
Electricity	57,41%	47,22%	63,80%
DH	16,47%	16,43%	36,20%
Natural gas	25,40%	35,34%	0%
Heating oil	0,73%	1,01%	0%

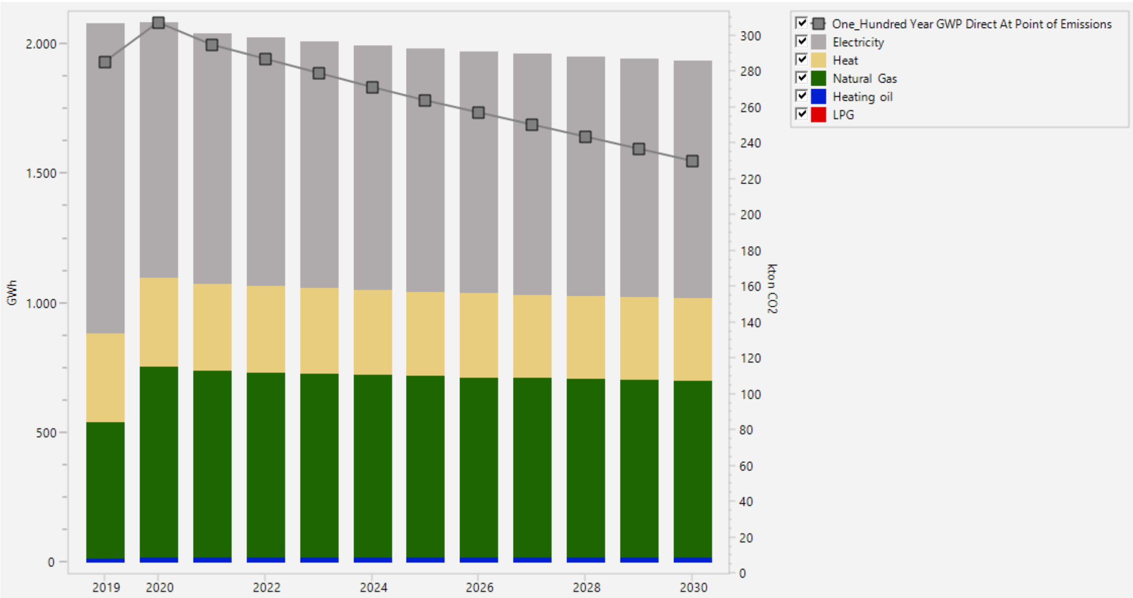

Figure 81. Private tertiary buildings energy consumption and GHG emissions in Riga SECAP scenario.

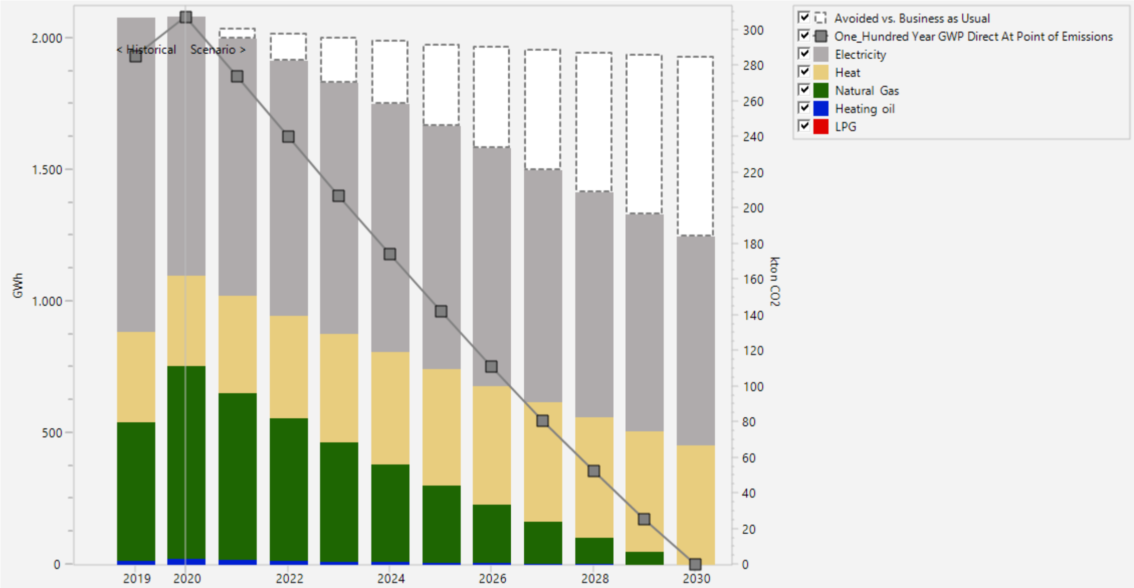

Figure 82. Private tertiary buildings energy consumption and GHG emissions in Riga Carbon Neutral scenario.

Municipal buildings

Regarding municipal buildings, SECAP scenario considers a 20% energy reduction objective by 2030 with regard the base year[34], whereas the Riga Carbon Neutral scenario aims for a 50% abatement by the same year. These reductions are assumed to be reached thanks to the implementation of energy efficiency measures (e.g. envelope renovation, renovation of heating systems, RES integration, smart energy management, etc…) Both scenarios assume the increase of electricity consumption as a result of the partial electrification of heat demand. Moreover, the sector is fully decarbonised in both scenarios since heat and electricity purchased for municipal assets consumption has to be green-labelled (i.e. carbon-free or coming from RES) according to the SECAP document.

It should be noted that energy data concerning municipal buildings is not fully available and only buildings connected to the DH are monitored (hence, buildings consuming other fuels for heating are not accounted). Data should be completed and revised to avoid inconsistencies in the establishment of energy abatement targets.

Table 50. Starting and final fuel mix in municipal buildings in Riga scenarios.

	2019	SECAP scenario (2030)	Riga Carbon Neutral scenario (2030)
Electricity	10,80%	24,18%	
DH	89,20%	75,82	

[34] On this concern, BaU scenario already contemplated the measures within municipal assets planned by the SECAP, therefore no differences can be appreciated between the SECAP scenario and the former.

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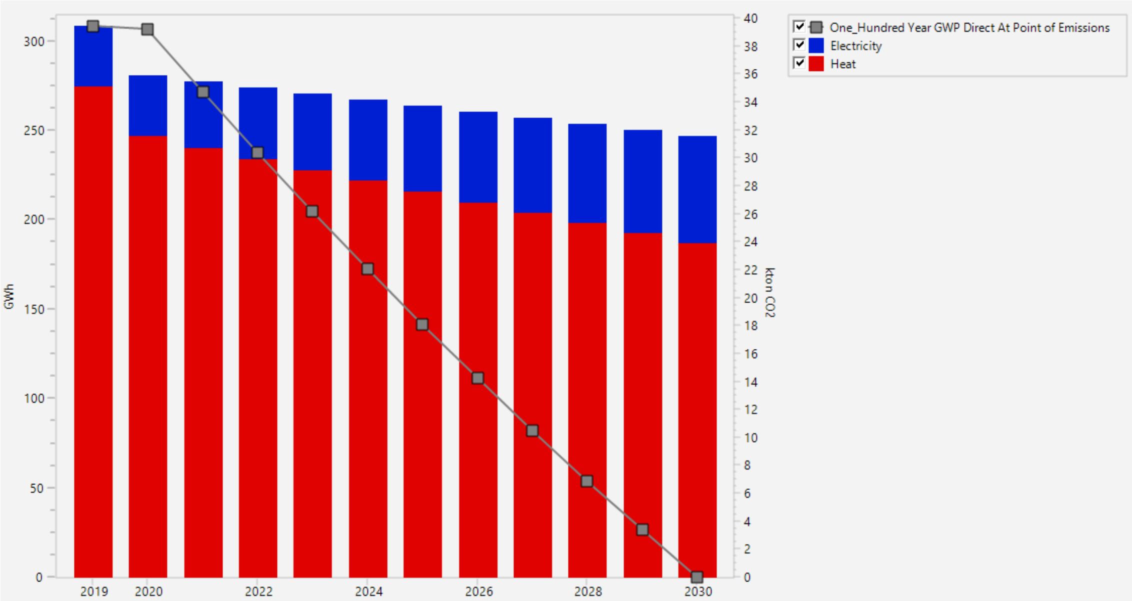

Figure 83. Municipal buildings energy consumption and GHG emissions in Riga SECAP scenario.

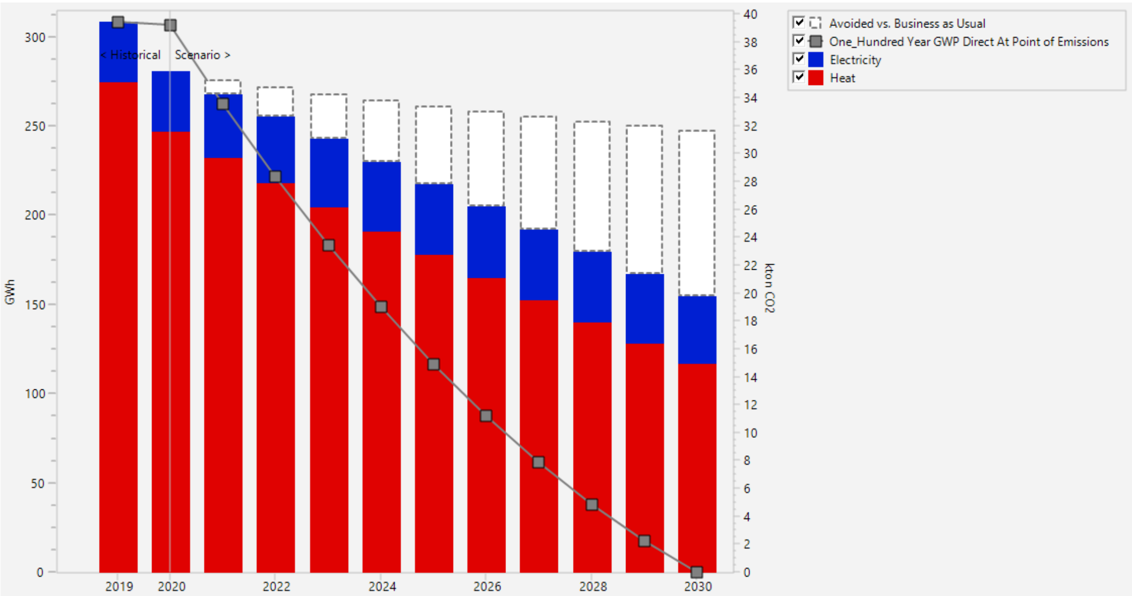

Figure 84. Municipal buildings energy consumption and GHG emissions in Riga Carbon Neutral scenario.

Street lighting

As in the BaU, both scenarios consider the full replacement of the city street lamps stock by LED lamps by 2030. Therefore, no differences amongst scenarios are observed. As for all municipal buildings, electricity used for street lighting is assumed to be green-labelled by 2030. Hence no emissions are reported related to this sector by 2030.

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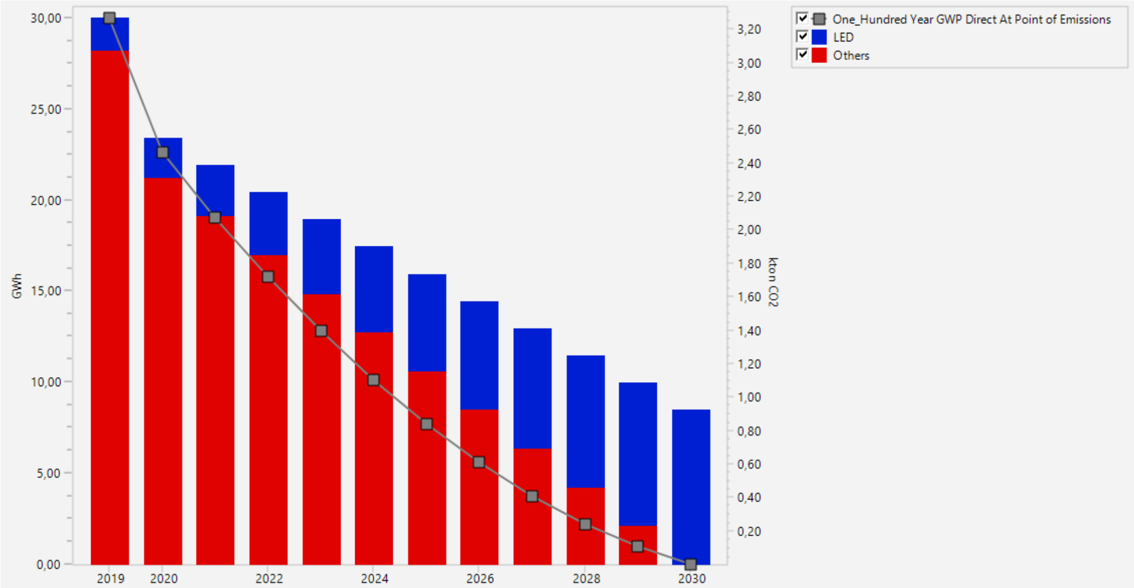

Figure 85. Street lighting energy consumption and GHG emissions in SECAP and Riga Carbon Neutral scenarios.

Water supply and sewage system

Concerning the water supply and sewage system the same 2030 abatement targets as for municipal buildings have been considered: 20% reduction with regard 2019 in the SECAP scenario and 50% reduction with regard 2019 in the Riga Carbon Neutral scenario. As for the rest of municipal assets, electricity purchased by the municipality is considered carbon-free. Therefore, the sector is fully decarbonised in both scenarios.

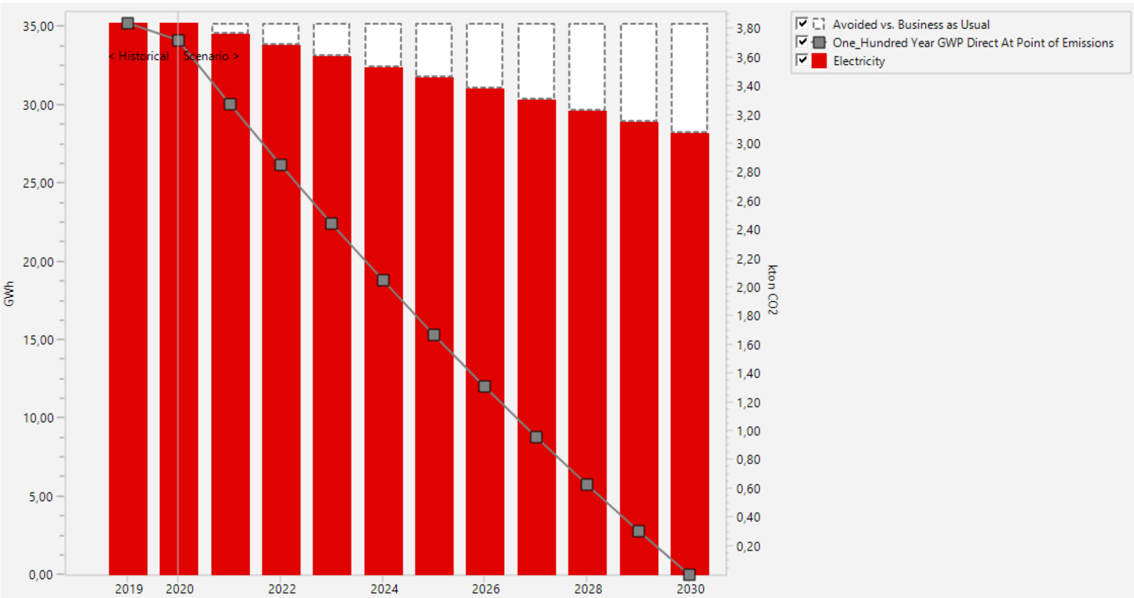

Figure 86. Water supply and sewage system energy consumption and GHG emissions in Riga SECAP scenario.

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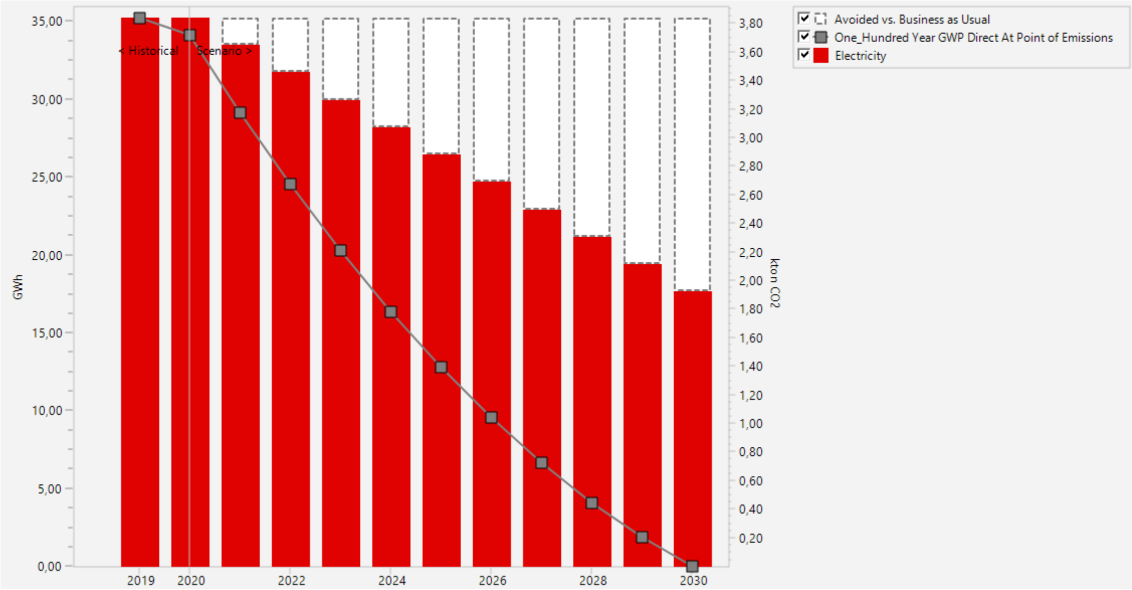

Figure 87. Water supply and sewage system energy consumption and GHG emissions in Riga Carbon Neutral scenario.

Industry

Since no measures regarding the industry sector are included in the SECAP document, the corresponding scenario follows the same evolution as in the BaU. The Carbon Neutral scenario however considers a reduction in energy consumption and a change in the fuel mix, phasing out natural gas and achieving the full decarbonisation of the sector.

Table 51. Starting and final fuel mix in the industry sector in Riga scenarios.

	2019	SECAP scenario (2030)	Riga Carbon Neutral scenario (2030)
Electricity	28,86%%	19,53%	40%
DH	6,19%	2,29%	10%
Natural gas	26,40%	31,30%	0%
Heating oil	0,22%	0,27%	0%
Coal	0,02%	0,02%	0%
Biomass	39,31%	46,60%	50%

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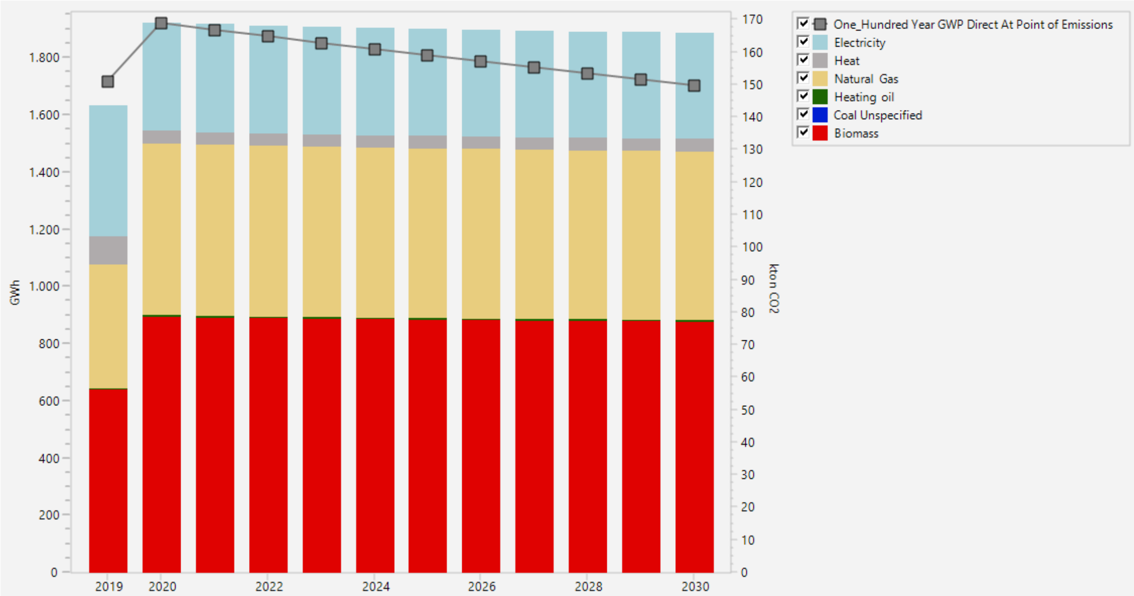

Figure 88. Industry energy consumption by subsector and GHG emissions in Riga SECAP scenario.

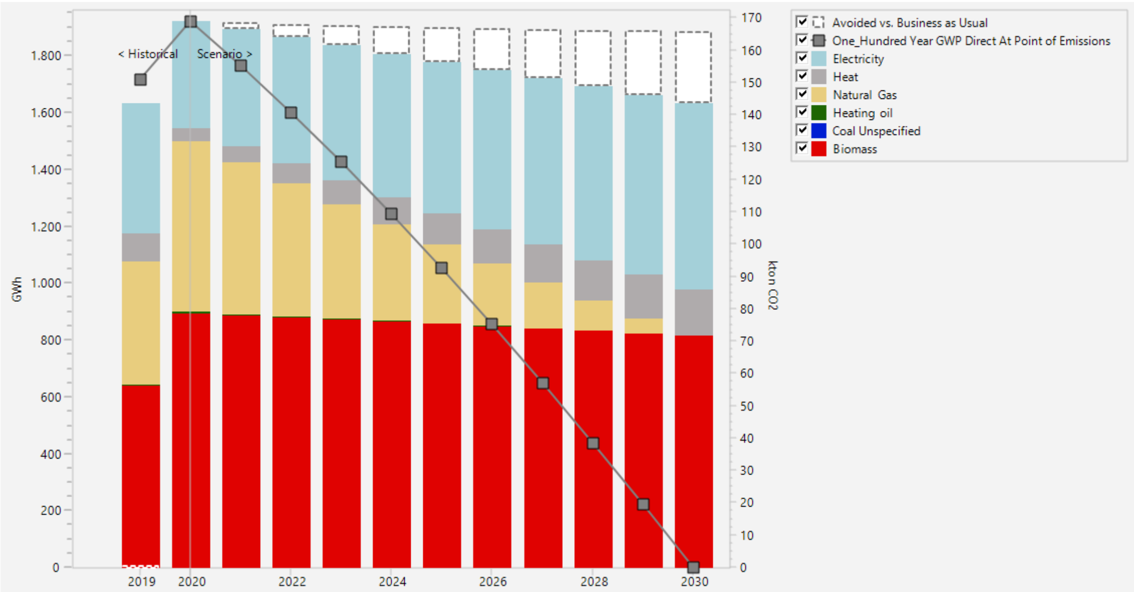

Figure 89. Industry energy consumption by subsector and GHG emissions in Riga Carbon Neutral scenario.

Municipal fleet

The whole municipal fleet is electrified in both scenarios. Energy is reduced thanks to efficiency improvement related to the shift in vehicles powertrains. In addition, since electricity used by municipal assets is considered to carbon-free, the municipal fleet is fully decarbonised by 2030 in both scenarios.

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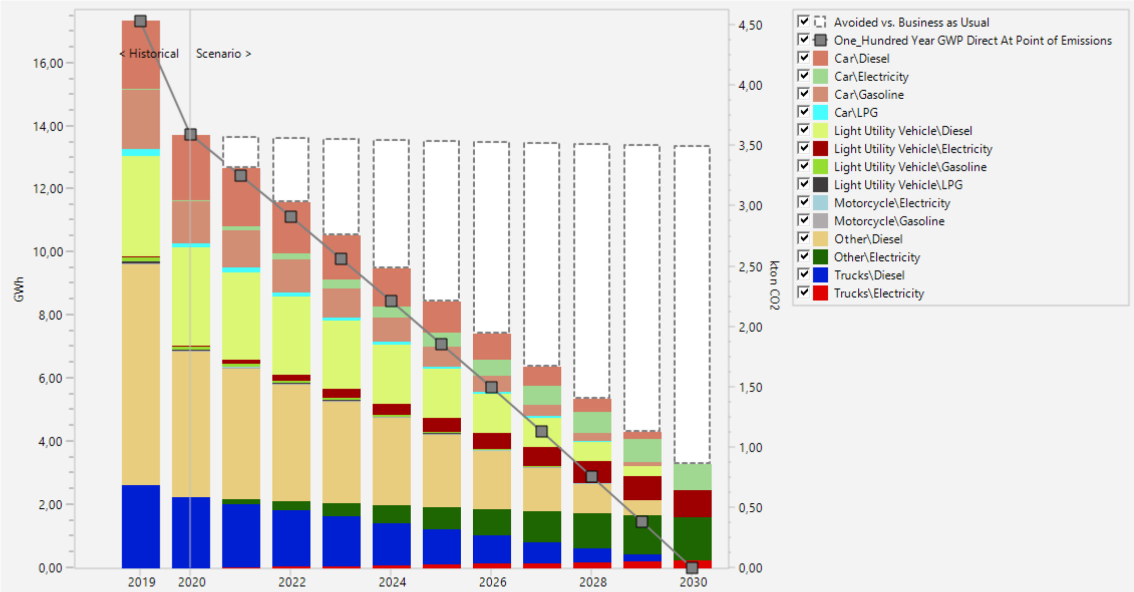

Figure 90. Municipal fleet energy consumption and GHG emissions in SECAP and Riga Carbon Neutral scenarios.

Public transport

Public transport demand in Riga is assumed to increase in both scenarios. However, this rise is offset by the partial and full electrification of the public transport fleet (buses, trolleybuses and railway) in the SECAP and Carbon neutral scenarios respectively. Indeed, half of the bus fleet is electrified in the former, while the whole fleet is electrified in the latter. Full decarbonisation of the public transport service is only reached in the Riga Carbon Neutral scenario.

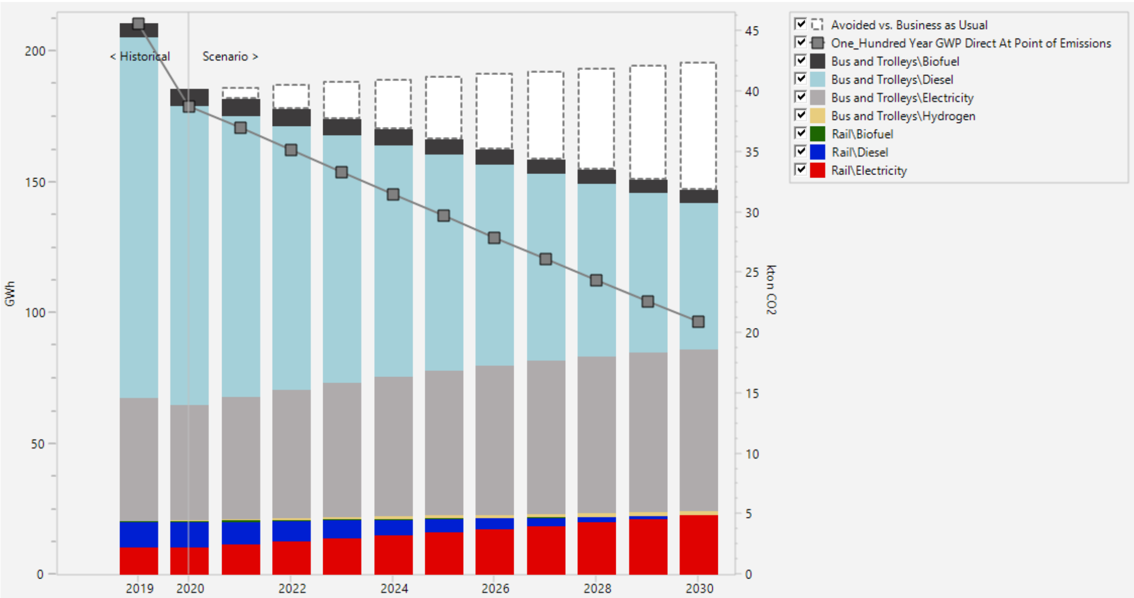

Figure 91. Public transport energy consumption and GHG emissions in Riga SECAP scenario.

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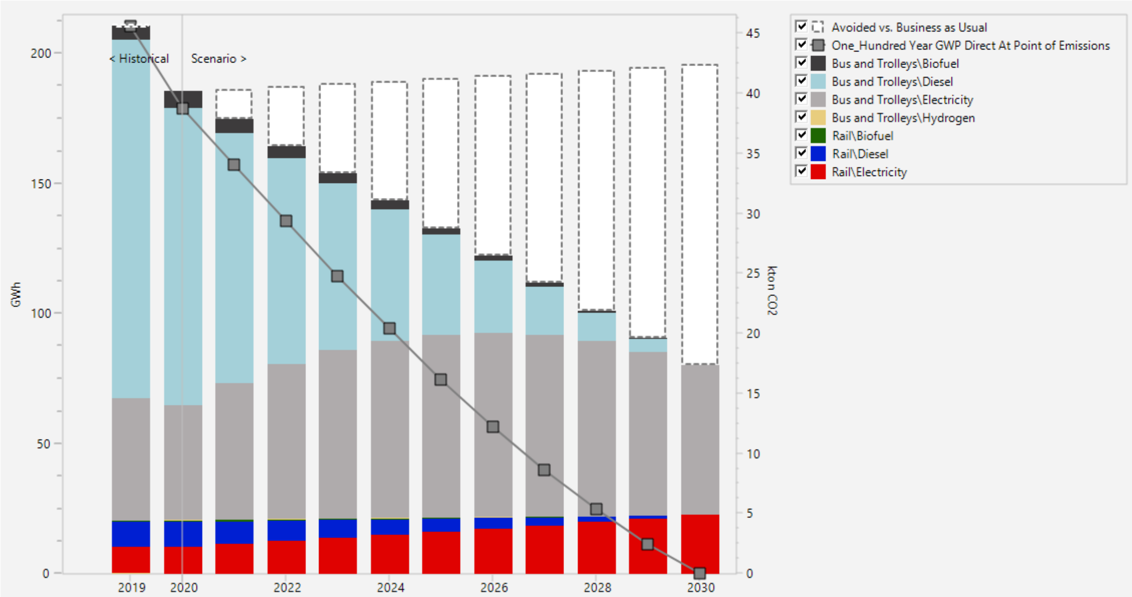

Figure 92. Public transport energy consumption and GHG emissions in Riga Carbon Neutral scenario.

Private transport

As a result of the implementation of mobility-related measures (e.g. low-emission zones, public transport and active mobility promotion, traffic restriction, parking policies, carsharing, etc…) the use of private transport is assumed to be reduced a 10% with regard the base year in the SECAP scenario and a 20% in the Riga Carbon Neutral scenario. This reduction, modelled through the reduction of the vehicle stock is complemented by the penetration of electric vehicles which achieve an extra energy and emissions abatement thanks to the improvement of the efficiency of the city vehicle stock.

Table 52. Fuel mix evolution by vehicle type in Riga scenarios.

		2019	SECAP scenario (2030)	Riga Carbon Neutral scenario (2030)
Two wheels	Gasoline	99,14%	80%	20%
	Electricity	0,86%	20%	80%
Cars	Diesel	55,64%	47,80%	7,80%
	Gasoline	36,60%	36,60%	36,60%
	LPG	5,50%	5,50%	5,50%
	Electricity	2,16%	10%	50%
	Natural gas	0,10%	0,10%	0,10%
Light utility vehicles	Diesel	95,07%	85,50%	45,50%
	Gasoline	3%	3%	3%
	LPG	1,10%	1,10%	1,1%
	Electricity	0,43%	10%	50%
	Natural gas	0,40%	0,40%	0,40%
Trucks	Diesel	100%	93%	80%

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	Electricity	0%	7%	20%
Others	Diesel	100%	93%	80%
	Electricity	0%	7%	20%

The combination of mobility measures (which reduce private transport demand and consequently the city fleet stock) and fleet electrification (which improves the fuel economy of the vehicle stock) reduce the energy use of the transport sector. However, the sector is not fully decarbonised in any of the scenarios due to remnant fossil-fuelled vehicles.

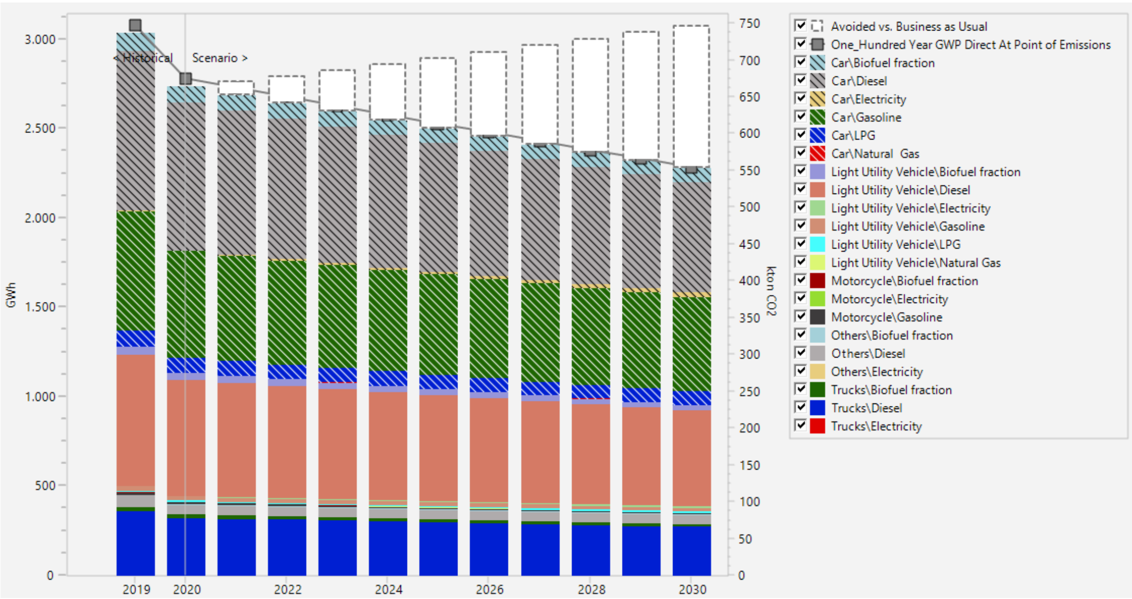

Figure 93. Private transport energy consumption (by type of vehicle and fuel) and GHG emissions in Riga SECAP scenario.

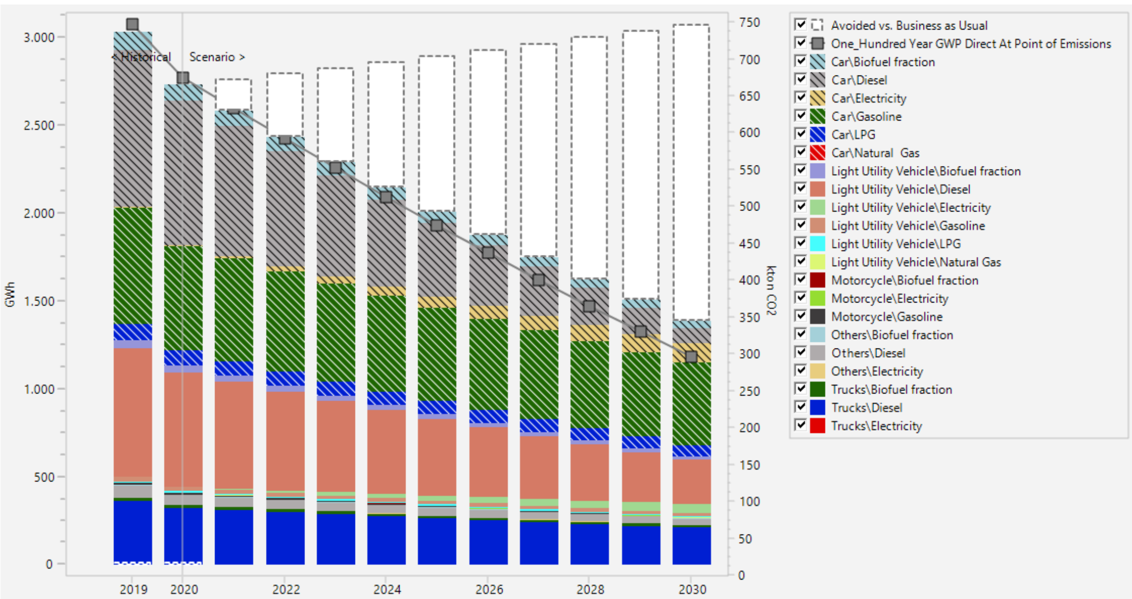

Figure 94. Private transport energy consumption (by type of vehicle and fuel) and GHG emissions in Riga Carbon Neutral scenario.

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Local energy generation

According to the SECAP, 66% of local heat generation will be based on RES by 2030. Conversely, in the Carbon Neutral scenario a 100% biomass-based DH network is assumed, hence achieving the full decarbonisation of the former.

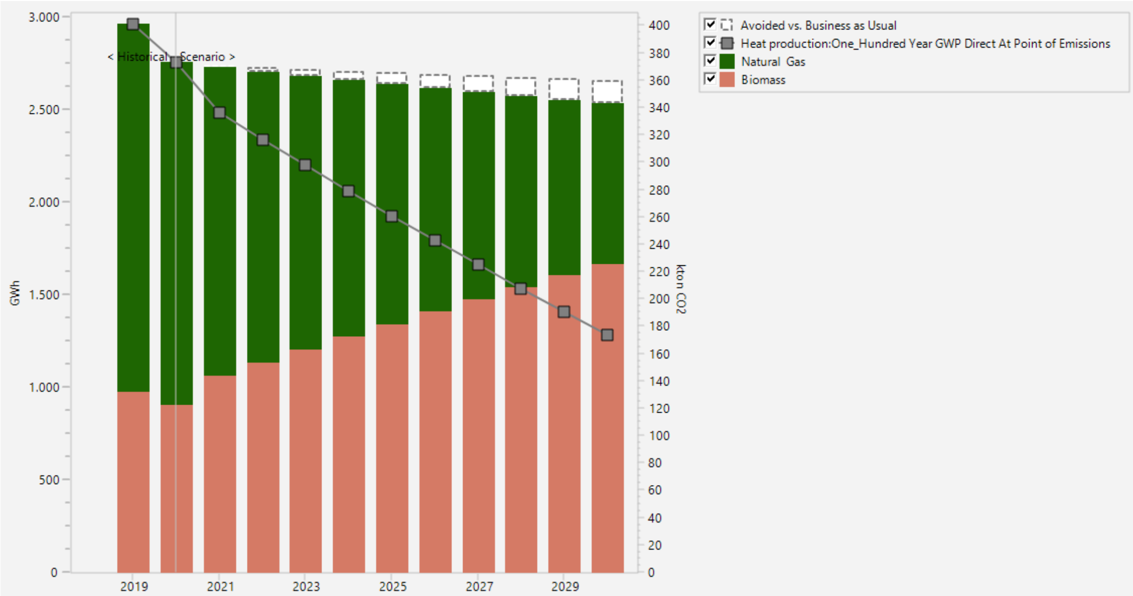

Figure 95. Evolution of local heat generation (and GHG related emissions) by feedstock fuel in Riga SECAP scenario.

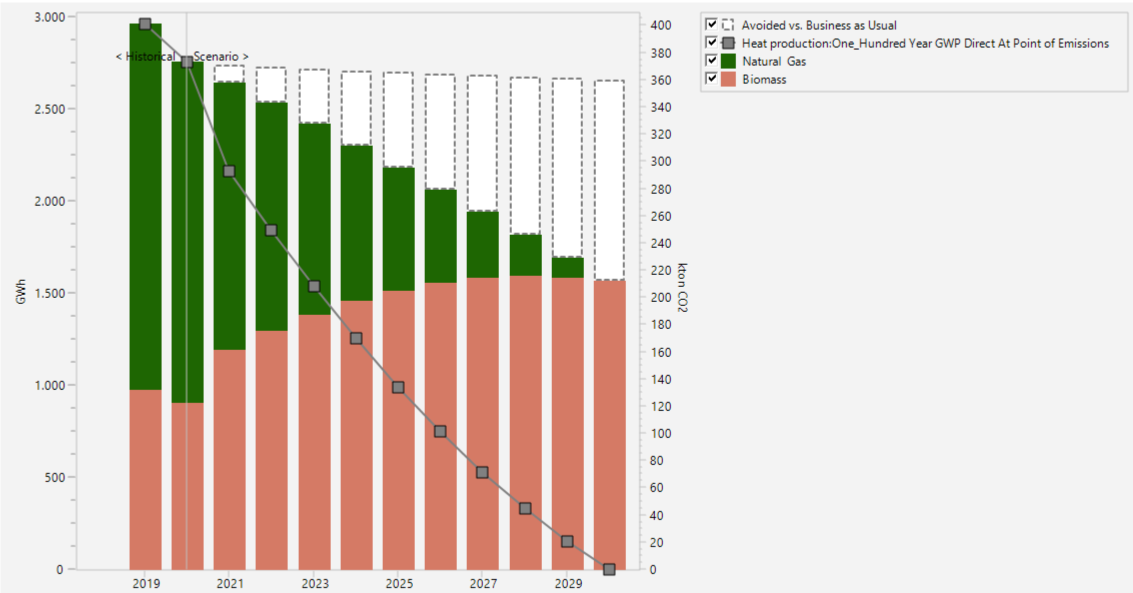

Figure 96. Evolution of local heat generation (and GHG related emissions) by feedstock fuel in Riga Carbon Neutral scenario.

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Regarding electricity, local RES generation is increased in both scenarios with regard the BaU (in which the electricity production was assumed to remain constant as the historical years). On the one hand, Riga SECAP scenario achieves a generation of 529 GWh by 2030 mainly coming from PV solar systems. On the other hand, in the Carbon Neutral scenario production reaches 1000 GWh by 2030with the relevant participation of wind technology. Finally, remaining electricity is imported from the national grid, which, in the Riga Carbon Neutral scenario, is assumed to be fully carbon-free.

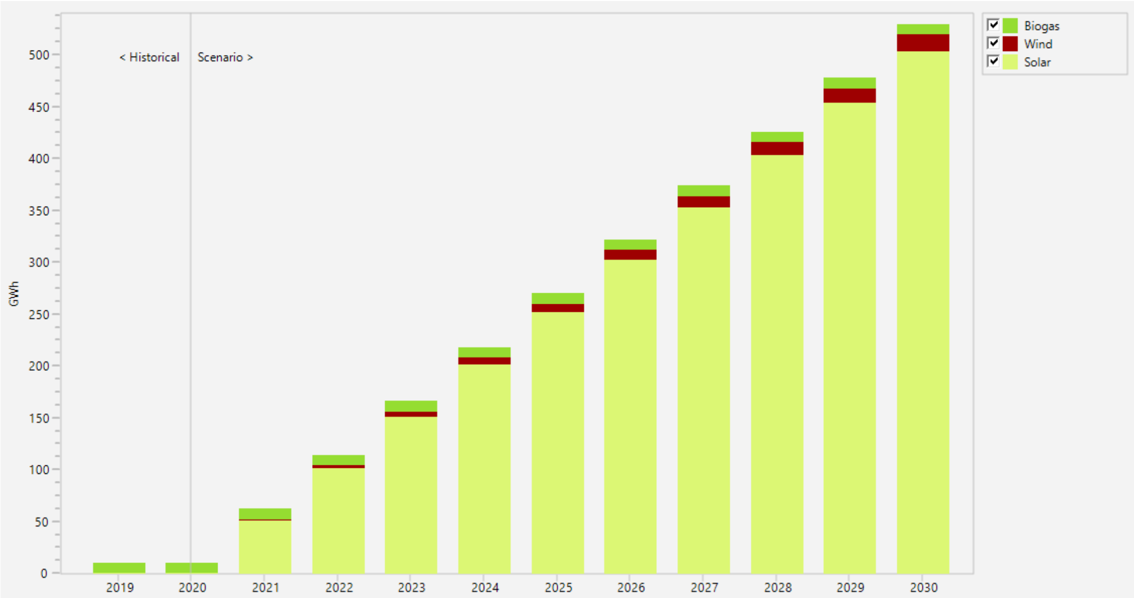

Figure 97. Evolution of local RES electricity generation by feedstock fuel in Riga SECAP scenario.

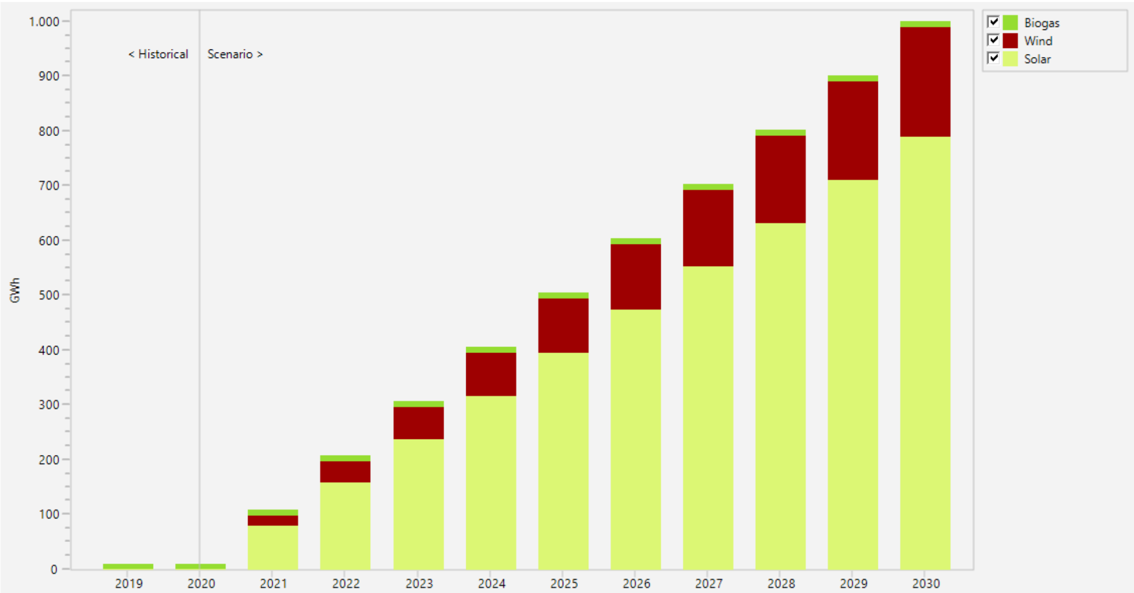

Figure 98. Evolution of local RES electricity generation by feedstock fuel in Riga Carbon Neutral scenario.

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4.8.4. The role of PED in City Vision

City of Riga is one of the cities in the "100 Climate-Neutral and Smart European cities" mission initiative. This initiative aims at accelerating the energy transition by supporting 100 cities to achieve climate neutrality already by 2030.

As for the cities in EU, buildings account for 40% of the total energy consumption [Directive 2010/31/EU], however, annually, only 1.3% of the residential building stock is undergoing a medium-to-deep energy retrofit. Further, transport in EU cities contributes a further 23% of greenhouse gas (GHG) emissions [EU Mobility Framework].

Developing Positive Energy Districts (PEDs), as introduced in the EU's Strategic Energy Technologies Plan, is a breakthrough way to deal with the issue of urban GHG emissions and applying adaptation and mitigation strategies to climate change, while ensuring that these urban areas generate an annual surplus of renewable energy and net zero GHG emissions.

Likewise other EU cities, also Riga is facing the challenge of redesigning the city to make it more sustainable, resilient, inclusive and safe, as captured by United Nations Sustainable Development Goal #11 and the New European Bauhaus initiative.

Tackling this issue at a district level – through PEDs – provides a framework to design the necessary building blocks to allow for upscaling across contexts, while also operating within the framework of a larger, e.g., national level energy infrastructure. PED solution shall address environmental, economic and social issues, providing solutions to energy consumption, production, emissions, transport, mobility and the overall liveability of the PED area.

The PED scenario studied within the ATELIER project for the Skanste district relies on a collective and inclusive solution, involving every occupant of the neighbourhood, in order to provide affordable renewable energy to each one of them and even produce an energy surplus available for surrounding neighbourhood, contributing to the achievement of Riga's climate goals by 2030.

Thanks to the PED development process Riga was able to learn lessons on how to achieve and how to implement (design, tender, etc.) a PED in the city as well as to realize what are the key constrains and barriers to overcome. The key lessons learn are the following:

- There is a favourable environment in the city of Riga to deploy PEDs, and a lot of political commitment.
- The decarbonisation of the DHN is a must to allow achieving an economically feasible PED (and also avoid oversizing technologies). Otherwise "virtual boundaries" are needed to become PED (by investing in a solar park).
- Currently (September 2023) there are some regulatory limitations, but the upcoming energy community's regulation seems promising, and it will hopefully change this landscape.
- Investment platforms could allow bringing additional benefits and making the investment more feasible. In most of the studied cases, participating in the collective PV with a shared of the investment provides benefits for the building itself and the district as a whole.
- The involvement of a variety of stakeholders (residential, district heating network operator, product developers, etc. like the ones in Skanste) will allow to share the risks, investments and achieve a more ambitious PED concept.

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Success of PED implementation depends, in particular, on active participation of (as many as possible) stakeholders and their empowerment as “prosumers”, producing and consuming renewable energy. Thus, the optimal PED solution in Riga city should be an inclusive solution, involving the occupants of the PED neighbourhood in order to provide them affordable renewable energy, as well as to produce an energy surplus, thus contributing to the achievement of Riga’s climate goals by 2030.

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5. Lessons learnt in City Vision creation process

5.1. The case of Amsterdam: 3 years of monitoring

As mentioned in section 4.1, the Amsterdam Climate Neutral Roadmap 2050 is in place as of Spring 2020. In this paragraph we will discuss the main lessons learned that have been identified in the development process as well as from the monitoring of the first three years of adoption of the ambition. First, we will present the **lessons related to the development process and the organization**. These can be divided in five main categories.

1. Defining of the process

With regards to the set-up and design of the process of establishing the Amsterdam Climate Neutral Roadmap 2050, the driving aspects were: splitting the development into content and process, clearly defining what can and cannot be discussed, setting concrete interim goals, allowing key stakeholders to take responsibility and ownership and continuously keeping each other up to date. To set this in motion, the climate neutral team made cooperation agreements within all transition paths to discuss annually what has happened and what has been delivered. In the implementation phase, internal stakeholders advice to hold on to the structure of the Roadmap, showcase what everyone is working on and create synergy between existing efforts. Moreover, it is crucial to remain sharp on the issues that arise and be honest and transparent about the feasibility and viability of measures.

2. Internal support

Additionally, it is essential to create internal buy-in for the Amsterdam Climate Neutral Roadmap 2050 in order to get it adopted and implemented. While the Roadmap was commissioned by the Councillor for Sustainability, to actually mobilize resources administrative priority and high-level support were also crucial. Freeing up time, money and people became a lot easier when the priority was widely recognized throughout the organisation. The climate budget was used as an instrument to get the entire municipal organisation involved. Sharing the insights on the current greenhouse gas emission, created a shared understand and responsibility of the challenge.

3. Integral approach

The Amsterdam Climate Neutral Roadmap 2050 has, for the first time, clearly mapped out what is needed to achieve the city's ambitions. Previously, there were various individual measures, but through this process it has now been analysed what measures are actually needed to become a climate neutral city by 2050. It shows that this ambition has an impact on all policy areas. Particularly in the discussion of the climate budget, the impact of the plans and emissions per portfolio have become even more insightful and more concrete. This also makes it easier to connect (existing) efforts to each other.

While many parties provided input for their own theme within the four transition paths, the process made apparent that the Roadmap is more than the sum of its parts; the integral approach has additional benefits which are now not clearly in scope.

4. Participation

Furthermore, participation is deemed an essential part of the Amsterdam Climate Neutral Roadmap 2050, in the set-up and design as well as in the implementation.

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One of the main reflections with regards to participation is that it proved to be difficult to get an overview of the entire stakeholder field and the possible role that these stakeholders could play in the realisation of the climate neutral ambition. Although it is evident that you cannot reach everyone, it is advised to take sufficient time to set-up their participation process and do an extensive stakeholder analysis.

In addition, the municipality has appointed initiative coaches and sustainability coordinators to link initiatives and target groups to each other. In practice, this still seems to be a challenge. Stakeholders express a need for a dedicated Amsterdam platform where people can be supported with tools to get themselves started.

5. Continuous progress

Now that the Amsterdam Climate Neutral Roadmap 2050 has been published, another huge challenge is the translation and integration of the ambition to concrete actions and into the daily operations of the municipality. The climate neutral roadmap is a joint product of various departments and all portfolio holders and councillors share its responsibility. Therefore, there should be ongoing coordination of the efforts by all departments, for example through a joint team with people working from these different departments. The focus of this team should be to constantly align ambitions and goals, but also think about the implementation, the feasibility of plans and actions, and the available instruments and resources.

After the lessons from the development of the Amsterdam Climate Neutral Roadmap 2050 we proceed with the **lessons derived from the first three years of monitoring**. We identify 6 lessons on the process:

1. Don't scope too narrow

For the successful transition from fossil to sustainable energy the focus should not only be on CO_2. Preconditions such as support and cooperation, knowledge development, space, capacity, regulations and finances are just as important, also to be monitored. And not the last place the pursuit of a just transition in which all Amsterdam residents can get engaged. These elements are, to a varying extent and sometimes qualitatively, included in the climate reports.

2. Crucial to monitor citizen support and manage participation

In the Climate Monitor 2020 it is mentioned that as plans become more concrete, it gets closer to the citizens, and questions and concerns arise. Support for an ambition and policy, doesn't necessarily translate towards support for a project. Exemplary is the process to search for locations to establish windfarms on the border of the city which gave rise to a strong societal debate. In 2021 the mini-citizen council was organized to derive additional measured to accelerate the energy transition and the wind energy reflection phase looked for new ways to do this in an innovative way with the city.

3. Maintain feedback and feedforward loops

The climate monitor includes mechanisms to both look back to the previous year, and look forward toward the near and longer term future. These mechanisms are subsequently relevant for the feedback loops towards the decision making process pertaining to the 2030 goal of 55% CO2 reduction and its translation towards concrete plans, projects and instruments. The monitor indicates in these feedback loops whether the city is on track towards the 2030 goal and where additional effort is necessary. In the 2021 monitor an intermediate goal is also

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established for 2025, this provides more direction towards the steps between 2020 and 2030. Included is a risk analysis for the energy transition and the realization of the climate ambitions and a fitting risk management strategy.

4. Monitor the needs for monitoring

It is important to also monitor the needs and conditions for monitoring as the transition progresses. A lesson learnt is that the implementation phase has different needs from the ambition or strategic phase. As a result, a decision in consideration is to relocate the monitor from team strategy towards the new municipal department which will be responsible for the implementation of the energy transition.

5. Include other governments and partners in monitor

It works well to include the questions and needs towards other governments and partners in the monitor. In this manner the monitor becomes a common and familiar place for the different stakeholders which helps in the current scattered field of policies, projects and instruments.

6. Adaptive and Aware

Over time new information becomes available as new or flanking policies are made, updated and operationalized in public services or projects, or as more research is conducted and information becomes available on e.g. new technologies. An effective monitor should be aware of this dynamic information provision and must be adaptive to take these into account. This does entail that it becomes even more important to be transparent in which information and which methods are utilized in the monitor.

Table 53. Summary of the progress

	Climate Report 2021	Climate Report 2022	Climate Report 2023
CO_2 emissions	12% relative to 2019 Expectation for 2030: 37% relative to 1990	3,5% relative to 2020 Expectation for 2030: 42% relative to 1990	7% relative to 2021 Expectation for 2030: 42% relative to 1990
Sustainable energy: PV	70% relative to 2019 124MW on roofs	30% relative to 2020 161MW on roofs	24% relative to 2021 199MW on roofs
Sustainable energy: Wind	-6% relative to 2019 62MW	21% relative to 2020 75MW	0% relative to 2021 75MW
District Heating and Cooling	8.000 connections added	5.400 connections added	5.500 connections added
Mobility	1.2% increase in electric km's	1.4% increase in electric km's	2.4% increase in electric km's
EV charging stations	42% Increase to 4.646	14% Increase to 5.280	12,5% Increase to 5.940
Citizen support	78% pro	85% pro	88% pro
Other	Closure of coal plant Environmental zone enacted	Environmental zone tightened	Insulation Offensive campaign started to tackle energy poverty

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Moreover, the following **lessons** can be derived on the nature and challenges of the energy transition in Amsterdam over its **four themes** of the Built Environment, Electricity, Mobility and Port and Industry:

Built environment (focus on heating and cooling)

- Making homes energy efficient preferably should be done in conjunction with housing quality and other (sustainability) transitions.
- Structural financing is required to realize the insulation/renovation task in the long term.
- Commercial market: Lobby towards the government for tightening legal obligations, including expanding the target group that is obliged to take energy-saving measures in the context of the Environmental Management Act.
- Lack of clarity about announced relevant new legislation and the non-binding nature of existing legislation hinders making agreements with private owners and commercial landlords. However, the government's public policy for the Collective Heat Act (WCW) will bring about a major change in the playing field and partners in the heat transition.
- The government does not (yet) provide sufficient resources and instruments to manage the energy transition. Amsterdam's Climate Fund is running out and will be replaced by the Central Government's Heat Infrastructure Subsidy.
- Becoming natural gas-free is not cost-neutral. Government subsidy schemes are largely insufficient to compensate building owners. The municipality does not have sufficient resources to deal with this for the entire city.
- Amsterdam residents in particular with a low or middle income should not encounter financial problems due to increased energy prices. Due to the legal no-more-than-otherwise framework, the end user in a natural gas-free building will not pay more than in the gas situation. To increase the acceptance of heat, it helps if it is cheaper than natural gas. In general, support and in particular affordability among private individuals (for owner-occupied homes and limited resources) needs to improve.
- The possibility of connecting to a collective heat supply within a period of a few years should be provided.
- Crucial factors for upscaling/acceleration are: more standardized approach, collective heating solutions, prioritization of neighbourhoods and targeted participation (especially if national politics makes this course possible).
- Heat companies decide on the use of heat sources. The municipality can only take on a facilitating role.
- The pace at which homes and businesses are connected to a heating network determines how many new heat sources can be fed into collective heating networks.
- The construction of heating networks requires long-term investments with uncertain payback periods. This slows down the inclusion of new sources.

Mobility

- Congestion on the electricity network impacts logistics: the municipality is committed to using the electricity grid as smartly as possible to prevent and avoid charging peaks.
- Facilitating the transition to emission-free with a comprehensive public charging network is challenged by the congestion on the energy network. The municipality is looking for solutions to this problem with network operator Liander, among others. The

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transition to emission-free mobility can also help to tackle congestion on the energy grid. Batteries in electric vehicles can be used as a storage medium/energy source. This can dampen peaks in supply and demand, allowing the electricity grid to be used even more optimally in the long term.
- Due to the effects of the corona crisis, the operation of public transport is still under pressure.
- The pressure on public space is high. For example, due to maintenance of bridges and quay walls, the space freed up by removed parking spaces can be used less for bicycle infrastructure or greening.

Electricity

- Solar PV
    - Amsterdam does not yet have the option to control the use of roofs for solar energy.
    - The available workforce, complex ownership structures, economic trends and government policy influence the growth in the number of solar panels.
    - The business case becomes difficult due to insufficiently sturdy construction on many large roofs.
    - Insuring solar panels is becoming increasingly difficult and requires more work and additional inspection costs. A guarantee fund could be set up for this.
    - Enhancing electrical connections by the network manager takes a lot of time.
    - Spatial integration of ground-based systems.
    - The corona crisis is causing companies to postpone investments in solar panels.
    - The lower rates of SDE++ subsidies are increasingly inadequate. This requires continued lobbying towards the national government for a more appropriate arrangement, which will allow continued use of the roofs.
- Wind
    - Integrating the new energy system sometimes leads to nuisance and resistance.
    - Communication about, and participation in wind energy projects must improve. Residents have concerns about their health and nature.
    - Determining search areas does not necessarily lead to the development of wind turbines.
    - Additional research is needed, including into competing space claims.
- Infrastructure:
    - Congestion on the electricity network has a major impact on the development of the city. To solve this, unconventional measures are sometimes necessary, such as the use of gas turbines or by asking major consumers to adjust their business operations.
    - Legislation and regulations are inadequate for some solutions, mainly in the areas of supply and demand management or the prioritization of (large) consumers.
    - The spatial impact of infrastructure enforcement is significant: substations, transformer houses and cables need to be constructed in many places in the city.
    - The government is developing new precautionary policy in the field of electricity and health (electromagnetic fields). The municipality takes this into account.

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Port and Industry

- A city-wide focus is needed on attracting personnel and administrative attention. For example, attracting innovation, startups, SMEs related to the hydrogen value chains.
- Spatial integration of the Energy Transition in the North Sea Canal Area, including the environmental and risk contours of hydrogen technologies in the area must be arranged.
- The latest coalition agreement aims to intensify the sustainability of the energy and industrial sector. The national government has also reserved major investments for this purpose in the coming years, which also offer good opportunities for the transition of the port of Amsterdam and the North Sea Canal area.

General

- Shortage of labour and raw materials is a riks for all transitions in Amsterdam. This is already an issue during education, relatively few students choose for technical education.
- The energy transition is also a social transition. To include everyone and achieve a just transition, investments must be unevenly distributed among sectors and socio-economic groups.
- Participation
    - Only a small percentage of Amsterdam residents understand that they have to get involved in the energy transition and take action. The largest group, the silent middle, still looks expectantly at what the movements are in politics and in society. More than 75% of Dutch people appoint the government as the 'executor' of the energy transition. The realization among Amsterdam residents that we need to tackle this collectively must accelerate. Good communication and participation can help with this.
    - Participation can be implemented in many different ways and always takes a lot of time and effort to implement properly. The available capacity at the municipality is a limiting factor in implementation.
    - Participation in times of corona has led to larger numbers of participants in online meetings. A point of attention remains that it is more difficult for us to reach vulnerable and less digitally skilled residents. In the future, events will take place both live, digital and hybrid. The experiences gained during the corona pandemic are used.
    - Space is needed to make breakthroughs outside the beaten path of financing and organization and to successfully develop the desired public-private partnership for the climate challenge.
- The climate crisis requires urgent measures which are part of the responsibility of the municipality. Therefore, in the near future choices are made that can hurt in the wallet or the environment.
- Innovation
    - Important to make optimal use of the region's innovative power to achieve the sustainability objectives.
    - An integral and long-term knowledge and innovation agenda is important, including multi-year mission-driven innovation programs.
    - Innovation requires creativity and an open mind within the entire municipal organization, with time and space to take risks and experiment.

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5.2. The case of Bilbao: front runner in Cities4ZERO methodology implementation

City Vision 2050 creation has been aligned to the Cities 4Zero Methodology presented by Tecnalia. Emphasising the need to involve all perspectives from an early stage, the first step focused on the recruitment and involvement of all relevant actors in the urban ecosystem. This phase has been active throughout the process and was driven by the local Smart City Planning Group (SCPG) governance model. Indeed, the constitution of the SCPG has been really valuable in order to improve the strategic planning process of the city of Bilbao and also as a great tool to integrate all relevant municipal areas and key stakeholders.

City of Bilbao recognized the public cooperation and institutional alignment as a key element for the success in its process of urban regeneration during the last decades. However, the lack of energy expertise and competences demanded a new configuration for the promotion of energy transition and specifically for the City Vision 2050. SCPG source was built on the Mobility and Sustainability commission, which main previous function had been to manage municipal assets (buildings, vehicles…) and the compliance of the Basque Energy Sustainability Law. The SCPG instead involves also other municipal entities, and external stakeholders as research institutions, energy agencies or universities or private enterprises in order to create a flexible and open ecosystem where the exchange of ideas is promoted.

To be honest, at first there was certain skepticism about the generation of a City Vision 2050 due to the uncertainty of determining realistic and specific objectives in that long term. However, the co-creation process embraces the knowledge of so many agents and consolidate a 2050 general overview that was really practical for the examination of applicable actions for 2030 year, that will feed into the SECAP, which the City of Bilbao is presenting in 2023. Indeed, ATELIER project has been a supportive context for the process of arranging several Workshops that provide an added value to the process. Beyond the SECAP, the basis for the development of the heating and cooling plan were established as well. The building stock analysis of the city developed in WP2 (see D2.5), was one of the inputs used in the development of the plan, which is in progress. Moreover, the city energy system analysis, including the diagnosis per sector, the scenarios business as usual and alternative, and the final master scenario, provided a deep knowledge in which city-decarbonization actions can be supported.

In short, Bilbao has benefited from the City Vision creation in order to define an interactive working group with the participation not only of municipal technicians but also of agents of all kinds. In addition, such a governance model also raised the awareness on the energy transition within the City Council the subsequent creation of the new Bilbao Energy Agency, BilboEner. BilboEner will be responsible onwards of all the energy efficiency interventions within the municipality. A possible area for potential improvement in upcoming processes might be the inclusion of citizens. City Vision 2050 has been agreed with specific associations, but it seems difficult to have a global representation of the whole citizenship.

Therefore, some of the lessons learnt include:

- It is needed to involve all the perspectives and points of view to gain in acceptance and in the success of actions implementation among others. A consolidated structure to facilitate the involvement is needed as well.

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- It is needed to apply a data-driven decision making approach to ensure that the resoluteness are well supported and will be effective.
- To facilitate the implementation of data driven approaches, the involvement of technical experts from different fields is needed.
- It is needed to learn while doing and being flexible in making adaptations and/or modifications if needed.
- A strong municipal department collaboration is needed to ensure the actions implementation.

5.3. The case of Copenhagen: working in post-neutrality plan

The overall impression from the climate vision work done so far is that everyone – citizens, businesses, institutions, and even politicians are interested and would like to know how they can contribute. Translating the climate challenge into clear cut everyday actions is sought after. Complexity creates hesitation.

The energy supply is well on its way to becoming Renewable Energy based. The actions needed now cannot always be directly linked to CO_2 reduction. How do we for example indicate successful sector integration and flexibility? So, how do we measure (and communicate) their success? And how do we compare them to other actions when we need to prioritise which actions to implement?

Easy access to correct up-to-date data and visualisation of these is very useful for debate and decision-making but are (still) far from easily available. Also, it is often assumed that systems (e.g., meters, district heat units) in place operate optimally while in reality they are not optimised and perhaps even malfunctioning. So basic maintenance and operation must remain an area of focus in any new plans.

The complexity of the transition requires more focus on communication. The energy crisis helped create a needed basic understanding of the causes of fluctuating energy prices and the link between energy markets. But there are still many other complexities. And how do we align political election horizons (4 years) with the political courage and long-term haul required?

The role of the municipality is shifting from decisionmaker to facilitator. This requires different skill sets and building partnerships. Using partnerships must be done with care and openness and attention to not creating distortion among segments or businesses,

Mobilising more entities and citizens typically requires more work hours. Resource allocation needs to take this in to account.

And finally, we are still novices in dealing with so-called super-wicked problems. This requires radical new ways of organising our efforts and we have little time to do so. This is difficult in a well-regulated society and large organisations. How do we signal progress if no clear targets can be identified? How do we prioritise our investments in a situation of uncertainty and rapid change? A linear approach where we start at A and end at Z is no longer suited to our situation at hand. We need to be able to operate and make decisions in a situation of flux and iteration.

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6. Conclusions

City vision creation is a process alive that must be supported in a robust local governance model to ensure the success of the strategies and implementations defined. Decision making in city vision creation must be informative. A deep understanding of internal mechanisms is needed and the study of different pathways to achieve desired objectives will provide the insights needed to enrich decision making and act.

ATELIER cities have defined their climate neutral city vision supported in the Cities4ZERO methodology (Bilbao, Bratislava, Budapest, Krakow, Matosinhos and Riga) or based on their own approach (Amsterdam and Copenhagen). The decarbonization of the energy system plays a crucial role in the climate neutrality pathway, but it is not an easy task. Cities are implementing different strategies to decarbonize their energy systems and, considering their current situation, they have characterized how they would like their carbon neutral energy system to be in the future.

As same as decarbonization strategies are different, modelling interests differ from one city to another. Although the same type of measures were considered and modelled (buildings renovation, heating systems renovation, LED public lighting, mobility measures, vehicles electrification, RES integration in heat and power generation, amongst other energy efficiency and decarbonisation measures), each city had their own specificities and particular scopes, timeframes, and objectives.

Indeed, on the one hand, some cities advocated for the modelling of scenarios where carbon-neutrality was achieved in the long-term (2050), while the short-medium-term (2030) represented the impact of their current SECAP or a first milestone towards the decarbonisation of the whole urban energy system. This is the case of Bilbao, Budapest and Krakow. On the other hand, other municipalities like Matosinhos, following the update of their commitments, supported the modelling of medium-term scenarios (2030) with a bolder approach in which the city achieved its carbon-neutrality by this year. The case of the city of Riga laid in between since the city was interested in the modelling of two medium-term scenarios: a scenario representing the impacts of the SECAP by 2030, and another one in which the city achieved its entire decarbonisation in the same timeframe.

This last approach is particularly helpful since it provides city stakeholders with insights regarding the different futures the city can face, while also quantifying the impact of different exogenous and endogenous factors (e.g. deployment of energy efficiency measures, socioeconomic events, etc…). This supports decision-making. On this concern, it should be also noted that for the definition of Bilbao's City Vision, three alternative scenarios were modelled with one of them resulting in the final Master scenario of the city.

Regardless the assessed timeframe, all cities aimed for a balanced approach in terms of considered/modelled measures in order to achieve carbon-neutrality. That is, all cities considered the renovation of almost the whole building stock, the decrease in transport demand, the electrification of heat and transport, and the deployment of RES (depending on the city specific technologies were preferable). Some cities included measures related to the industry sector which were harder to assess and whose assumptions had to rely on national policy. Finally it is important to note that, the decarbonisation of the national power grid, as well as on the decarbonisation of their own local heat network (if present) was key in the effective decarbonisation of all cities. On this concern, according to the modelling, some cities would

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still had to compensate remaining emissions (mostly from transport and industry) to achieve their effective decarbonisation.

This deliverable is a proof of the remarkable effort that ATELIER cities are doing to decarbonize their energy systems. They have created mechanism to involve all the relevant stakeholders that have to be part of the process, they have collected and analyse their energy system related information, they have reflected about the most suitable pathways to become carbon neutral and, after numerous discussions they have established their city vision and a viable master scenario that will allow to accomplish it.

Moreover, ATELIER cities are already working in developing or updating their action plans or their climate city contracts according to the city vision and master scenarios set in this deliverable. This information will be presented in next steps of the WP2.

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