Smart-BEEjS

Human-Centric Energy Districts: Smart Value Generation by Building Efficiency and Energy Justice for Sustainable Living

Techno-economic Aspects and Pathways towards Positive Energy Districts

Status quo and framework conditions as a basis for developing techno-economic pathways in selected case studies

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1 Introduction

In Europe, urban areas are the largest contributors to climate change, while also being home to around 3/4 of the population, as well as the main drivers of the European economy. Thus, the European Union (EU) recognises the need to reduce energy demand and CO_2 emissions in cities whilst making them more attractive, competitive, sustainable and healthier places to live in. Several EU policies and initiatives support this intention, such as the energy union strategy, the Urban Agenda for the EU, the energy performance of buildings directive (EPBD), the EU Covenant of mayors for climate & energy, and the European Strategic Energy Technology Plan (SET Plan) [1]. “Smart Cities and Communities” as one of the SET plan’s focus areas approaches the decarbonisation of the city energy system holistically, specifically by bringing forward the development and implementation of Positive Energy Districts (PED)[1] [2]. The goal is to have 100 PEDs under planning, development, or operation in Europe by 2025 [3].A PED should balance three main functions, namely energy efficiency, flexibility and energy production, while following quality of life, inclusiveness and sustainability as the main guiding principles [4].

The implementation of such a concept faces several challenges in relation to: the local energy infrastructure context, such as social, technical and economic context of energy generation and use; the building stock conditions; the policy framework at the national and regional level; the perceptions and awareness of stakeholders; and the needs that derive from emerging users, such as electrified mobility.

The purpose of this report is to present **the context that frames the development of potential PEDs (named as Framework Conditions[2])** in a selection of European cities (Frankfurt, Germany; Vienna, Austria; Nottingham, UK; and Torres Vedras, Portugal). These cities are selected as case studies because they have expressed the political will to introduce the concept as part of their decarbonisation strategies and participate as Partners in the Smart-BEEjS project. On the other hand, each case is also assured to draw a diverse picture in terms of climate conditions, district status (existing or planned) and population density (details of selection criteria, in Appendix A). By collating secondary information, the aim is to provide local policy makers (e.g. city and town councils) examples of recent attempts on the path of decarbonisation of cities or districts[3], raising awareness of different approaches to implement the same objective. Furthermore, at the next stages of the Smart-BEEjS project, this work will be the basis for the techno-economic models of the relevant districts in order to present potential scenarios of pathways for the transition of a district towards an operational PED.

The report is structured in the following way. Section 2 of the report presents the template of analysis for the Framework Conditions in our case studies. The analysis of the four cases are presented in Sections 3-6. Finally, Section 7 concludes with an outlook that is intended be of interest to municipal authorities.

[1] PED: *“energy-efficient and energy-flexible urban area which produces net-zero greenhouse gas emissions and actively manages an annual local or regional surplus production of renewable energy”* [4]

[2] Framework conditions originates from the German term “Rahmenbedingungen” and is thus mainly used by German speakers in English to describe the German policy environment [248]. When referring to framework conditions in this work, we refer to *the business, technical and regulatory context in which governments, citizens and economic actors operate and interact to achieve a specific goal.*

[3] The terms “city” and “municipality” are used in this report to denote both the administrative unit (city, parish, etc) and its governing body (i.e. local government), so they are sometimes used interchangeably. We use the term “district” as an official administrative division within a city (e.g. Griesheim) and the term “neighbourhood” as a non-official, usually smaller, part of a district or a city (e.g. Griesheim-Mitte).

2 Framework Conditions – A Template of Analysis

Each case (district, city or region) enters into this transition journey from a different starting position that reflects the local political culture, the past priorities of development, and the innovation and mix of their energy system. The template of analysis of these framework conditions can be a challenge in itself, as there is no defined method. Based on the SET-Plan 3.2 report and the recent white paper on PED Framework by JPI Urban, the research team defines five different but closely interlinked **dimensions of analysis** (Figure 2-1) that represent the key challenges and necessities for the emergence of a PED [2] [5].

1. **Policy Framework – regulatory, planning and coordination context**: the deployment of PEDs requires policy support and coordination at the EU, national and regional level. The way that policies are formed and implemented often conditions interactions with opposition groups or different citizen initiatives. This might happen because of lack of awareness, understanding or cooperation among the different stakeholders;

2. **Built Environment – building stock conditions**: efficiency of the building stock, their "history"[4] and space conditions (e.g. rooftops, basements or other free areas) can be decisive factors that define the potential of the district to be transformed into a PED, especially regarding heating/cooling demand and energy generation ability;

3. **Energy System – energy supply and consumption**: this area includes the technologies already present in the energy generation mix, but also the socio-economic ability of the community to adapt to the new technological needs and consume them effectively;

4. **Mobility and the transition to sustainable mobility**: e-mobility might play a big part of the decarbonisation effort of cities. However, e-mobility is part of a wider transport system with emphasis on reducing car use and initiating active mobility (e.g. bicycle use, walking). The development of sustainable mobility depends on the existence of a transportation infrastructure which is convenient, fast and not costly for potential users, as well as, on the ability of the energy system to generate and cover safely and economically the necessary energy load for the electrification side;

5. **Stakeholders**: the way that policies are formed and implemented can affect the existence and nature of opposition from different groups or citizens or businesses. This might happen because of a lack of participation and cooperation among the different stakeholders or competing interests. In the case studies we recognise the relevant stakeholders in the energy, heating and mobility networks and wherever possible discuss their participation in planning and strategies. This is a "horizontal" dimension that is considered in parallel with each of the other four.

Each case in our analysis (Sections 3-6) presents the starting conditions of that city or district emphasising one or several of these dimensions[5], as these have been identified by secondary sources of information. For each case, the vision of the city in relation to energy and climate issues are identified. The research team then determines key infrastructure settings in relation to the energy-

[4] Building age, previous retrofits.

[5] The cases do not have detailed information regarding all five dimensions or similar level of detail at the district level. Furthermore, these five dimensions are formed or analysed at different levels, for example, policy framework or stakeholders are usually of municipality-level, whereas building stock condition can be better evaluated at the neighbourhood or district level. Collectively they provide the multidimensional picture for these and other cities to understand their initial position.

efficiency of the building stock, the energy system mix and actions to foster the switch to a sustainable mode of mobility. Finally, relevant stakeholders, whose roles in reaching the set target are essential, and their engagement levels are defined across all the other four dimensions.

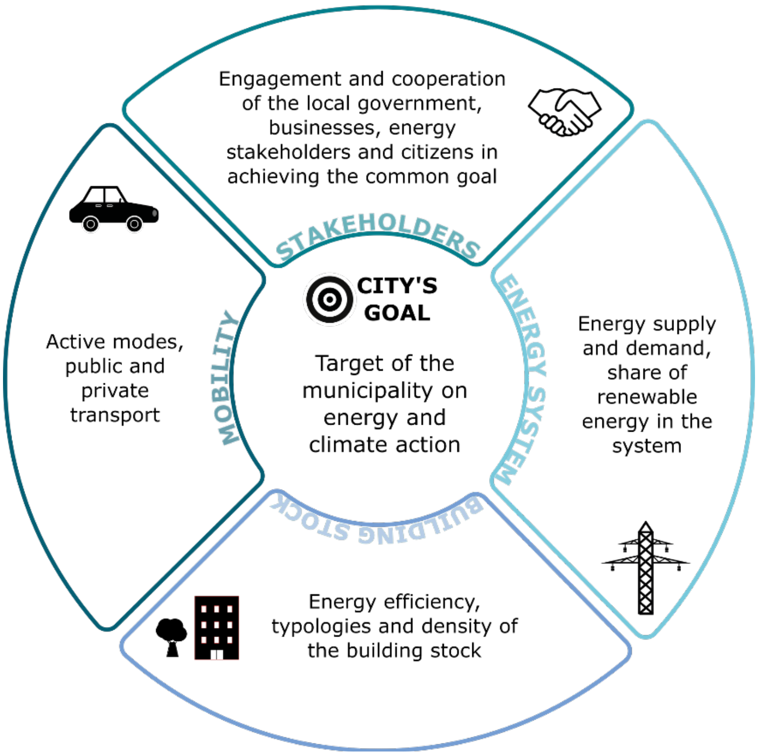


Figure 2-1. Representation of the analysed dimensions

The analysis according to these dimensions are also the basis for the future work of this Working Package, that is, the development of a methodology for systemic planning of infrastructure investments based on socio-techno-economic models. These models will examine the infrastructural requirements, focusing on different elements of PEDs (microgrids, district heating, etc), necessary for these municipalities and districts to implement and transition towards PEDs. Hence, they need both quantitative and qualitative information that helps recreate the real-life case in the model. For example, details such as the current share of renewable electricity, local energy demand, existence and characteristics of district heating described in the “Energy system” are very important input information for the future models. As a result of such further work it will be possible to provide recommnedations at city level and design transition pathways towards PEDs.

2.1 Policy Framework – Regulatory, Planning and Coordination Context

With the ongoing decentralisation of energy systems and local production of renewable energy, or district heating, ***local governments’*** role in energy planning, coordination and regulation is becoming more important [6]. Simultaneously, measures and policies cannot be realised without the ***acceptance and participation of the public*** and the cooperation and competence of the ***stakeholders in the local energy systems***. Of particular relevance are those stakeholders whose well-being and profit is affected the most by the decision of the public policy. These include the energy supply, transmission and operation actors (Transmission System Operator – TSO; Distribution Network Operator – DNO; district heating network), or demand side actors (residents and residential building owners; transport operators and providers; industrial user and building owners). Stakeholder engagement and consultation is becoming a key component of the policy-making in the EU [7]. However, often the speed of decision and policy-making at the international or national level have pushed cities and municipalities to move on their own. For example, by introducing local climate and energy plans and establishing national, transnational and international governance networks [8] [9] [10]. These plans however, have to engage back with intranational or national programmes to reach finance, or to organise public-private partnerships.

Whereas some municipalities might have clear roadmaps and have already introduced local measures, other localities might have less clear strategies and have taken fewer or less ambitious actions. Some municipalities might be ready to start implementing PEDs, whereas for others, this might currently pose a more significant challenge. Though strategic energy planning and developing local energy and climate policy frameworks remain most of the times a voluntary action, some European municipalities are driving energy transition from within, for example through the Covenant of Mayors [11].

The following themes are selected to examine the local policy environment in each case, which will frame the development of PEDs:

- **Current energy or climate policy goals and strategies.** A municipality's current climate protection goals and energy strategies are the foundation for policies, regulations and local actions. Policies on the EU, country, or state/region level and across different sectors – renewable energy, building, and mobility need to be considered. Moreover, the priorities that the local community places are highlighted by the focus areas of a policy framework and the roadmap of implementation.
- **Financing mechanisms of local measures.** Funding – including for institutions and programmes – is a crucial element of implementing as well as the speed of implementation of any policies and measures towards energy decarbonisation.
- **Participation mechanisms.** Specific examples of policies, including citizens and stakeholders' participation, can be identified that may facilitate the development of PEDs.

2.2 Built Environment – building stock conditions

Buildings lie at the heart of any neighbourhood or district and have implications on the energy consumption by its occupants. In particular, heating demand as well as space available for potential energy generation (e.g. rooftops, basements or other free areas) can be decisive factors that define the potential of the district to be transformed into a PED. Thus, the following relevant aspects related to the building stock are considered in each case:

- **Efficiency of the building stock**. As renewable energies have a lower energy density compared to fossil fuel, it is important to decrease demand so as to cover energy needs as much as possible through RESs only. The current state of buildings with respect to age and geometry determines how energy efficient they are, especially when it comes to heating and cooling. This will also influence how policies are prioritised and implemented to tackle and future proof the building stock.
- **End use of the buildings**. Different end uses mean different energy demand. Whereas an apartment requires heat to only provide a proper thermal comfort a small number of people, large offices need to do the same for a larger amount and often in tighter spaces. Industrial buildings might use heat or electricity to keep a blast furnace active. These activities are more energy intensive and pose greater difficulties but also opportunities when planning a PED.
- **Population density and availability of space**. A high population density implies that the space requirements to cover the local energy needs using local Renewable Energy Sources (RESs) is

rather more challenging than in less populated areas (e.g. rural areas), as space availability to install more renewable energy sources might be reduced or not large enough to meet the internal demand in PEDs. Therefore, the energy density and population density might pose further complications in the implementation of any energy plan that involve the deployment of decentralised energy sources.

2.3 Energy System – energy supply and consumption context

The current electricity and heat generation mix in parallel to the energy consumption patterns determines to a large extent the potential ability of CO_2 emission reduction of a city or a district. In this regard, the definition of PEDs is strongly reliant on the positive annual energy balance between locally produced[6] surplus energy fed into the distribution grid and imported energy [2]. Deployment of distributed energy resources, such as residential rooftop PVs or micro-CHPs, is an example in the attempt of achieving a positive net balance. Energy consumption by end-use, on the other hand, shows if energy is mainly consumed as electricity, heat or fuels for transportation and can potentially direct the PED measures to areas with most impact potential.

Therefore, two sides of relevant infrastructure context are considered in this analysis:

- **Energy generation mix**. The level of distributed energy generators within the district (for electricity, heating and cooling), local generation (e.g. through roof PV, partly used for self-consumption, or through local renewable energy communities), or the mix of use through the main grid is considered in the different cases. The *actual physical delivery* of the electricity is carried out via the TSO (Transmission System Operator – for long distance high voltage) and the DNO or DSO (Distribution Network Operator – for final delivery to consumer, low-medium voltage). The role of capacity and ancillary services markets are increasingly important in a distributed generation system and are additional enablers for the TSO to maintain grid stability. On the side of heating and cooling, often cities or districts explore options such as district heating networks that are fed by Combined Heat and Power (CHP) plants or Combined Cooling, Heat & Power (CCHP) plants or utilise shallow, low temperature geothermal sources. Most often though residents and other users generate heat through the main gas grid.
- **Energy consumption**. The city's or district's major consumers (e.g. residential users, industrial users, or mobility) defines the share of the final energy needs and patterns in relation to electricity, heat or transportation. The energy consumption pattern is related further to the two major dimensions of the study: the building stock conditions and the emerging use of e-mobility. The identification of outlier consumers is crucial as they might require special attention regarding PED measures but might also reveal the potential for waste heat usage. Such outliers could be specific energy-intensive industries such as data centres for electricity or steel industry for heat, compared to the district average.

2.4 Mobility and the transition to sustainable mobility

Transport is one of the largest energy-consuming sectors in EU, contributing 31% in 2017, with road transport being 73% of all transport modes [12] [13]. Therefore, the urban mobility system plays an important role in the energy transition strategy. It is also very relevant for the development of PEDs,

[6] Locally generated energy primarily refers to energy generated within the set district boundaries. However, in a virtual PED, other constitutions are possible such as community-owned assets out of the district boundaries. Locally generated energy shall be of a renewable nature [247].

as the positive balance of energy in a future PED should not be outweighed by the energy intensity of local transport and mobility infrastructure. Moreover, the uptake of e-mobility can be a part of the solution that will add to a positive balance of a district (e.g. by creating a level of flexibility through storing energy). Finally, the economic and social urban development depend on the existence of a transportation infrastructure that is convenient, fast and not costly for potential users.

Sustainable transport is gradually becoming an important part of good practice in urban planning [14]. Maltese et al [15] identify two groups of Sustainable Mobility (SM) indicators: (1) direct and (2) indirect. The first group contains all the indicators that have a direct effect on mobility, the infrastructure and modal choices, i.e. expansion and effectiveness of the public transportation system, strategies for reducing car use (e.g. car sharing; car-pooling; collective taxi; bike sharing), bicycle and pedestrian paths, planning parking spaces (e.g. planning typologies, open air, underground, park & ride, etc), alternative fuelled vehicles. The second group includes all other measures, such as land use policies (e.g. mixed use of land and density), new technologies (e.g. applications of data use) and raising the awareness of environmentally friendly aspects of Sustainable Mobility (e.g. campaigns, training for use of new technologies), creation of new jobs in the sector, empowering engagement of citizens and public-private partnerships.

This report focuses only on the **direct criteria** in the presentation of the case studies: (1) active modes of transport, (2) public transport, (3) private motorised transport. Cases are presented at the municipality level, as the relevant practices are applied usually at that level, zooming whenever relevant to the district level for more details (e.g. charging stations, bike-sharing stations, etc.):

1. **Active modes of transport**, or active mobility, are forms of transport that uses only human physical activity. The most common forms are walking and cycling, though other means are also possible (running, skateboarding, using roller skates, etc.) [16]. This theme investigates:
   - the share of pedestrians and cyclists in a municipality (i.e. modal share)
   - availability of bicycle and pedestrian paths
   - measures of bicycle and pedestrian encouragement.
2. **Public transport** in most of the European cities include railway, road transport and, in some cases, water navigation. The following is identified under this theme:
   - modal share of public transportation
   - effectiveness and integration of public transport system (including intramodality)
   - alternative-fuelled public transport.
3. **Motorised private vehicles** including cars, motorcycles, and trucks accounted for 72% of all emissions in transport sector in the EU in 2016 [17]. Thus, it is interesting to see what the modal split for private road transport is, as well as what measures are taken for:
   - reducing private car use (e.g. services such as car sharing, car-pooling, collective taxi, bike sharing)
   - restricting the incentives for private transport (e.g car-free zones, speed reduction)
   - incentivising alternative fuelled vehicles, etc.

2.5 Stakeholders

Ambitious targets are hard to realise without the support, cooperation and competence of the **energy system stakeholders**, such as actors representing the energy supply, operation, and demand areas (i.e. buildings, transport, industry). Operations and revenues might be affected by the decisions of the policy makers and the pressure of the public to decarbonise the system. Therefore, stakeholder engagement and consultation is becoming a key component of policy-making in the EU [7]. The electricity system, district heating and mobility stakeholders are the three predominant sectors considered in this study. The dimension of stakeholders is considered horizontally in all the other four dimensions of our case analysis.

2.5.1 Electricity system stakeholders

Typical actors of a simplified **electricity system** are illustrated in Figure 2-2. In the EU, those stakeholders are characteristically present in a similar manner in each member country. Thus, they are generally described here and within the case specific sections the specific actors are introduced.

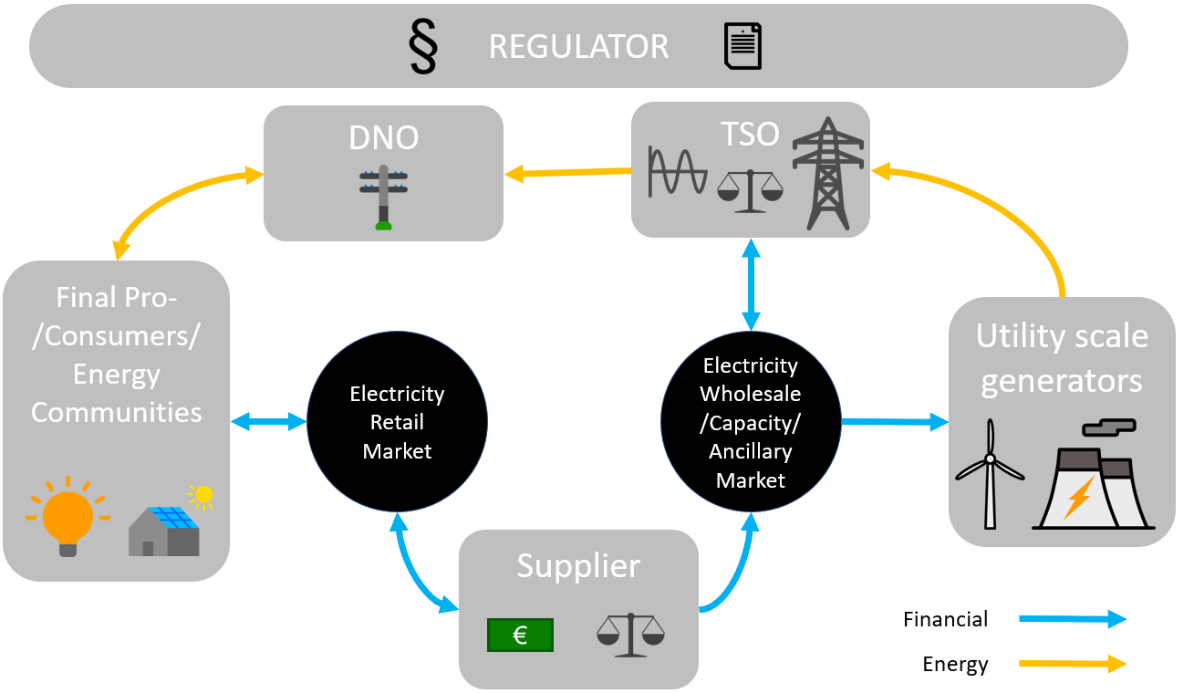


Figure 2-2. Classical interaction of simplified electricity system stakeholders

Large scale power plants powered by fossil fuels, nuclear and renewable sources generate most of the electricity. The regulators’ responsibility is to establish the rules of the market and system [18]. The utility generators sell electricity on the wholesale market to suppliers, which then sell it through the retail market to the final consumers. In case the final consumer is a small-scale electricity generator, and thus a prosumer, or a small renewable energy community, there is usually a regulation to sell the electricity back to the supplier, sometimes incentivised by feed-in tariffs. This represents the *monetary market side* [18].

2.5.2 District heating

Unlike in the electricity system, there is no regulatory scheme for the operational structure of district heating. Whereas in some places, the owner of the combined heat and power plants are the same as the district heating network, some countries mandate they should be separated. As there is no precise legal framework, it is not possible to draw the same conclusions as done for the electricity supply. The stakeholders might vary considerably from case to case. Furthermore, not all cities have heat supply through a district heating network, and in some cases, there is no intention to build any. Therefore, district heating stakeholders are introduced directly in the relevant case section.

2.5.3 Mobility stakeholders

There are numerous urban mobility stakeholders, such as local transport authorities, transport operators and providers, car sharing companies, bicycle rental operators, major employers and SMEs and local communities, users of the transport services. At the local level, relevant public administration units are responsible for planning and implementing transport-related actions as a part of the urban development plan [19]. In contrast, citizens and users (e.g. large businesses or SMEs located in urban areas) are service users or owners (e.g. cars, bicycles) and are directly affected by the changes in the transport system. Public transport operators/providers are mostly private or state-owned companies. Finally, private actors (and their associations) are directly involved in providing (e.g. operators of technology-based mobility services) or being active users of the infrastructure (e.g. logistics operators, “final-mile” delivery) [20].

3 The case of the Griesheim-Mitte, Frankfurt am Main City

Case ID: Griesheim-Mitte (Frankfurt am Main)

The city of Frankfurt (Frankfurt am Main) is the centre of the Functional Urban Area of Frankfurt *(Stadtregion Frankfurt)*, the largest city in the Federal State of Hesse, the fifth biggest city in Germany [21]. The city is known for its international financial centre, airport, trade fairs and is a global and a European hub for trade, transportation, tourism, culture and education.

Frankfurt has its own elected mayor, who is the head of both the City council and the local executive body named *Magistrat* [22]. The city has 16 Area Districts, i.e. administrative divisions (*Ortsbezirke*), each with its own local committee and chairperson – which are arranged in order to involve citizens into the municipal self-administration process [23]. They manage 46 City Districts (*Stadtteile*), which are further subdivided into 122 city boroughs (*Stadtbezirke*) [24].

Griesheim, City District No. 19, is situated in the western part of the city, to the north of River Main (Figure 3-1(a)). Mainzer Landstraße Street and the railway divide the district into 3 parts: *Griesheim-Nord, Griesheim-Süd* and *Griesheim-Mitte* (Figure 3-1(b)). North Griesheim is predominantly a residential area with buildings from early 1950s and a local recreation area Niedwald [23]. South Griesheim is characterised by the industrial park in the western side and the district centre with a variety of shops, restaurants, cafés, and other services. **Griesheim-Mitte** is the central part of Griesheim district. It is characterised by the residential buildings concentrated in the eastern part, a commercial area with data centres, large retailers, parking spaces, and other businesses in the western part. The population of Griesheim-Mitte is about 8000 people [25]. The demographic structure in the neighbourhood is characterised by a large proportion of the internationals and Germans with migration background [26].

Griesheim-Mitte has been recommended in our project by the local government representatives, as it is currently under redevelopment using Integrated Urban Planning process, with an interest to go further and become a PED [27].

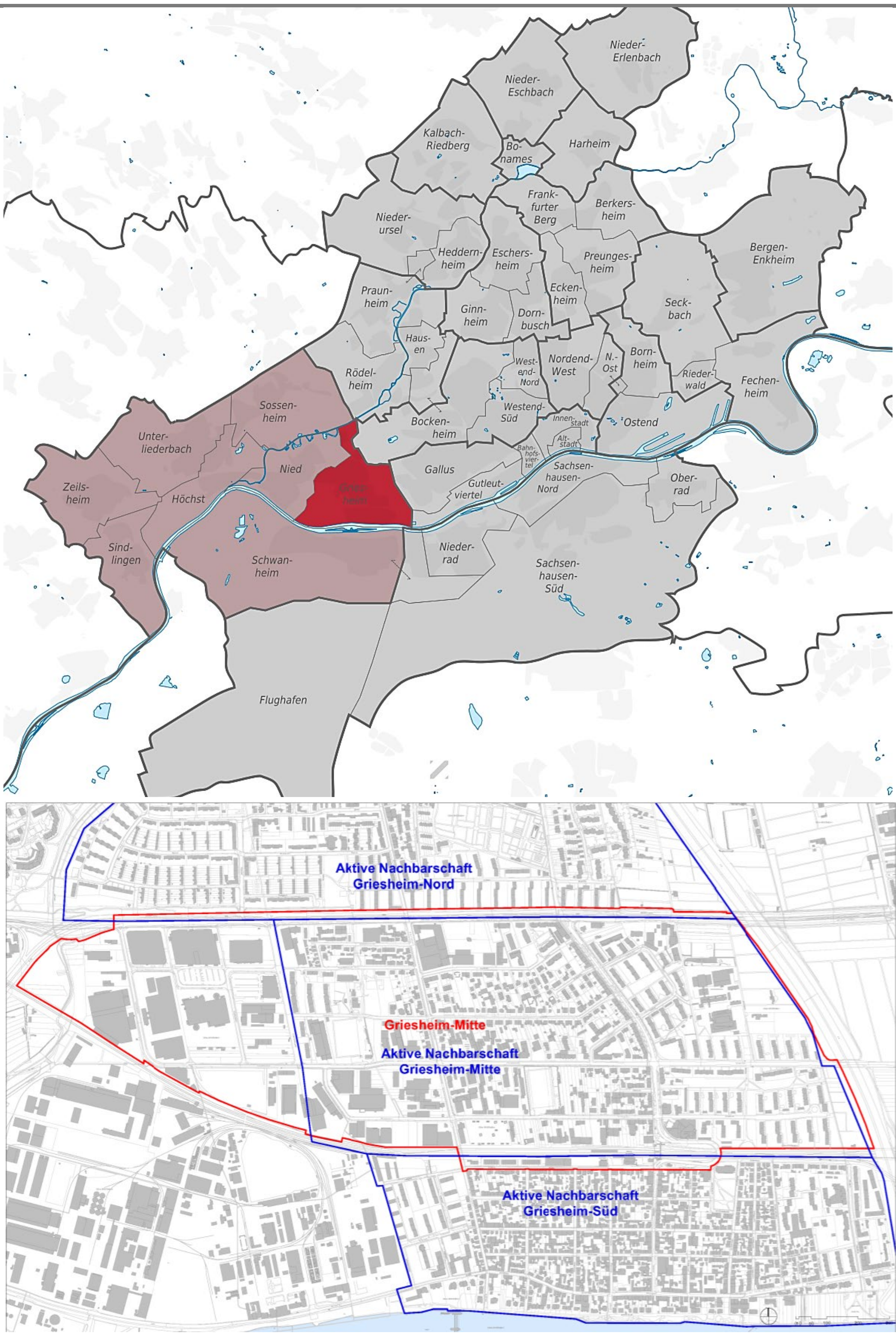
Key priorities: Redevelopment of Griesheim-Mitte to facilitate the decarbonisation and social cohesion in the district.

Key achievements:

- Identification of existing PV, solar thermal and process waste heat potential;
- Retrofits of selected housing blocks;
- Establishing the participative planning process for the redevelopment of Griesheim-Mitte;
- Setting up the Neighbourhood management office to support and connect residents, local stakeholders and local government.

Key challenges: Techno-economic barriers in the implementation of the district heating with waste heat, such as, supply and demand mismatch and profitability of waste heat recovery system.

(a)



(b)

Figure 3-1. (a) Location of Griesheim-Mitte in Frankfurt [28]; (b) Griesheim-Mitte

3.1 Policy Framework and Policy Stakeholders in Frankfurt am Main

The City of Frankfurt has a versatile set of sustainability related policies in the last two decades. Decisions are taken at the highest level of the City Council and Magistrat, which form the highest executive body and, thus, the "government" of the city of Frankfurt. The implementation then is transferred to specific departments[7] (Dezernat) of the council, with responsibility of detailing the plan and monitoring the implementation of specific aspects of the projects (Figure 3-2), or outsourcing to expert external organisations[8].

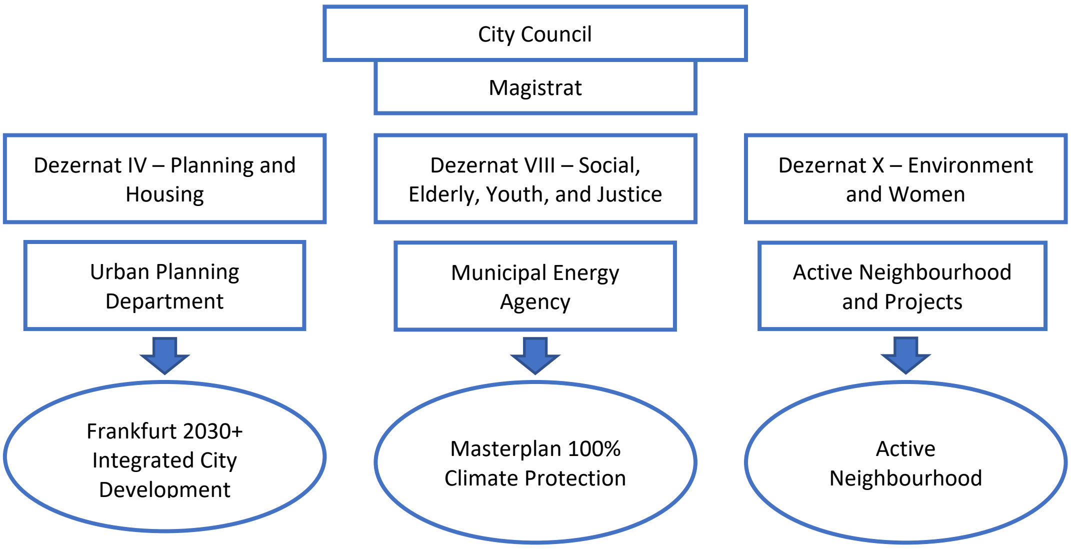


Figure 3-2. Administrative structure of the policy framework

As early as 2007, the municipality implemented the Passive House Standard – one of the important steps to decrease energy demand of local buildings. A resolution passed by the City Council requires that all new buildings on a municipal-owned land must be built according to the Passive House standard (except when it is not possible for structural reasons) [29]. Furthermore, the Municipal Energy Agency takes the responsibility to advise potential buyers and lessees of urban properties in the implementation of the passive house standard, reviews planning specifications and support the optimisation of public transport infrastructure.

Frankfurt am Main participated in the federal programme *"Masterplan 100% Climate Action"* (Figure 3-3), which was initiated and funded by the Federal Ministry of Environment, Nature Conservation and Nuclear Safety, for the period between 2013 and 2018 with a budget of €500,000. The aim of this programme was to help municipalities to produce a strategy for reducing their greenhouse gas emissions by 95% by 2050 compared with 1990 levels and decrease final energy consumption by 50% [30]. The remaining energy demand is aimed to be covered by local renewable energy sources [31]. The General Concept for achieving the set target was approved by the City Council in 2015 and currently serves as a foundation for political decisions [32]. In the subsequent years the potentials and

[7] Relevant departments: Road Traffic Department (Straßenverkehrsamt, Amt 36); Urban Planning Department (Stadtplanungsamt, Amt 61); Department of Building and Real Estate (Amt für Bau und Immobilien, Amt 25); Land Surveying Office (Stadtvermessungsamt, Amt 62); Construction Supervision Department (Bauaufsicht, Amt 63); Agency for Housing (Amt für Wohnungswese, Amt 64); Road Construction Office (Straßenbauamt, Amt 66); Green Areas Office (Grünflächenamt, Amt 67); Water Department (Stadtentwässerungs, Amt 68); Municipal Energy Agency (Energiereferat, Amt 79)
Frankfurt Economic Development (Wirtchaftsförderung Frankfurt GmbH, subsidiary company)

[8] For example, the Neighbourhood managers hired by a non-profit organisation that provides service in the field of youth employment, social and educational work in Germany (Internationaler Bund (IB), 2020), as well as the project steering group for the Urban Redevelopment represent the executers and the link to the residents of the district.

suggestions, identified in the General Concept, were formulated into a concrete action plan, annually summarised in the "Building Blocks for Climate Protection" [33]. In parallel, the city appointed a Climate Protection Manager to oversee the future development. The Masterplan 100% Climate Action is closely intertwined with *"Frankfurt 2030+ Integrated Urban Development Concept"* (*"Integratives Stadtentwicklungskonzept*"), which commits the city to develop in a climate-friendly and a socially-inclusive way [34], maintaining high quality of life and sustainable environmental conditions.

Two municipal programmes were initiated in the district of Griesheim-Mitte, aiming to improve housing and living conditions and to strengthen local economy and social cohesion enhancing social and cultural life, and empower active citizens [35]:

- **Urban redevelopment and renovation process** focuses on infrastructural changes (i.e. construction, retrofit, or redesign of the neighbourhood) and is financed by the federal-state program "Urban redevelopment in Hessen" ("Stadtumbau in Hessen") [27].
- **Active Neighbourhood** *("Aktive Nachbarschaft")* tackles the "social" aspects of life in a district by providing Griesheim-Mitte with own Neighbourhood-managers[9] in charge *(Quartier-manager)* available at fixed hours to address the concerns, problems, questions, and recommendations of the local stakeholders [35].

One of the key elements in the realisation of the "Urban Redevelopment" is the participation of the residents in the planning as well as implementation of the project. This is done by forming a Local Partnership with 15 representatives from the residents and 14 representatives from the organisations and companies in the neighbourhood. Each of them has a right to vote, thereby influencing the project planning and implementation processes [36].

To sum up, the current climate and energy policy pathway related to Griesheim-Mitte is depicted in Figure 3-3.

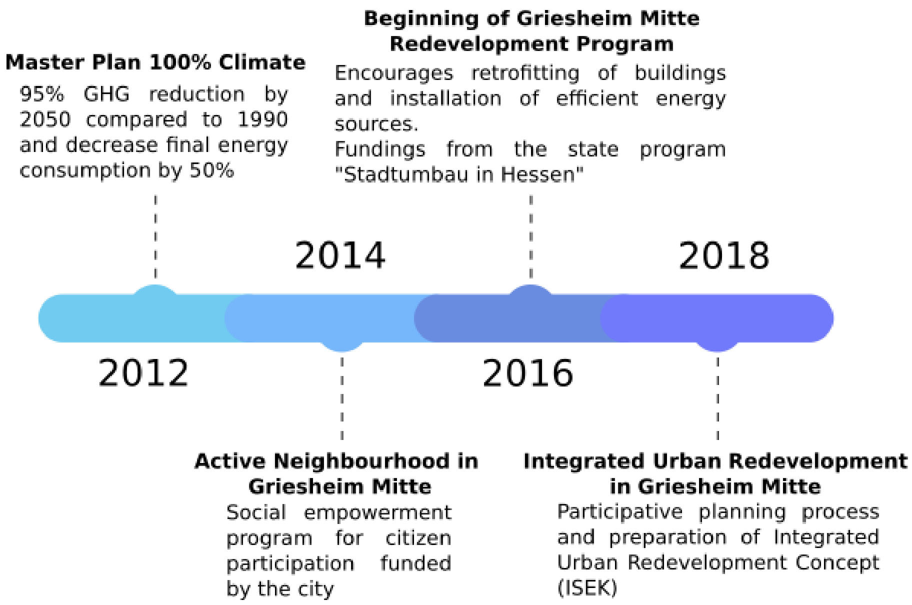


Figure 3-3. Climate and Energy Policy pathway of Frankfurt

[9] The Neighbourhood managers hired by the Internationaler Bund are supported by the Frankfurter program and subsidized from the municipal capitals, namely by the Dezernat X.

3.2 Building stock conditions in Griesheim-Mitte

Griesheim-Mitte extends on 121 ha, of which 97 ha is built-up area. The approximate 610,000 m^2 Net Floor Area (NFA) is divided among five subareas that demonstrate different characteristics (Figure 3-4) [25]. There are 657 buildings, of which 548 are residential (Figure 3-5), mostly distributed in the subareas 2, 3 and 5. Subareas 1 and 4 are almost exclusively designated for commercial, business and industrial buildings. Section 4 has residential buildings along Walschulstraße, a road that traverses this part of the Griesheim for about 200 metres. Despite the business, commercial and industrial, having only a small share of the total amount of buildings (79 buildings in total), they still present an extension of 201,257 m^2, almost matching that of the residential structures.

Figure 3-4. Division of Griesheim-Mitte subareas

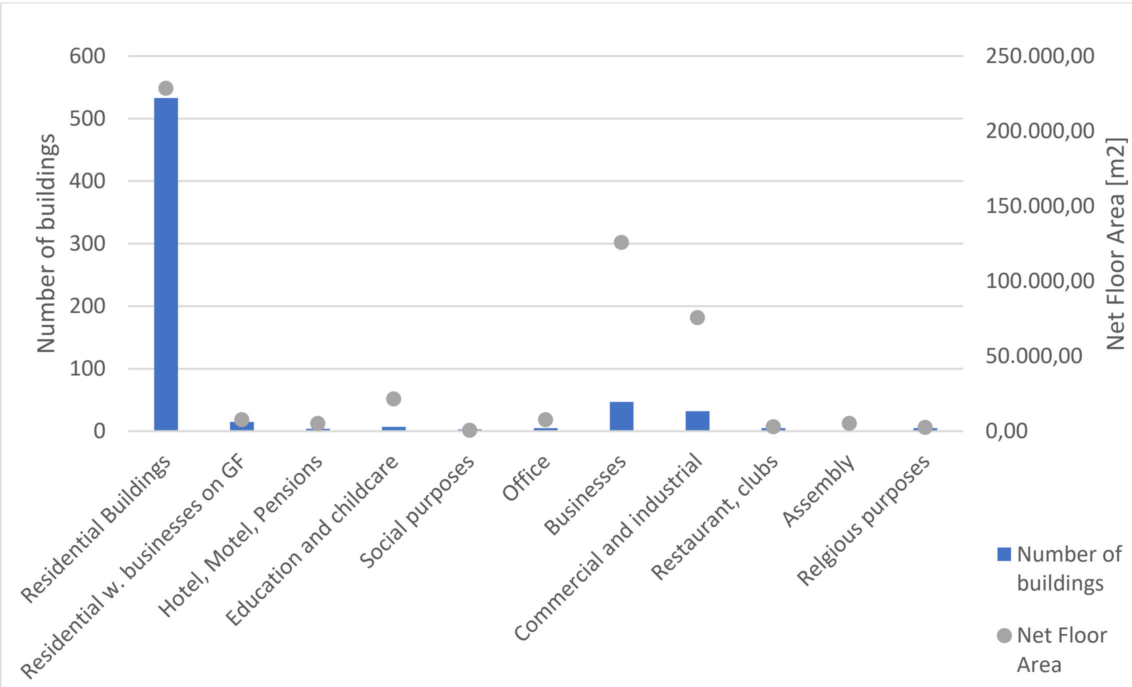


Figure 3-5. Number and Net Surface Floor Area of buildings divided by use [48]

Residential buildings in the area present a large variation in regard to type and age. For example, it is possible to find detached and semi-detached houses, multi storey buildings with small businesses at ground floor, row and multi-family houses. The age of the residential units varies considerably, with some of the buildings dating prior to 1920 and others after 2005. Most of them though were built between the 50s and the 60s (Figure 3-6). The energy demand varies considerably between the age categories of the buildings (Figure 3-7), with the ones built during the 1970s and 1980s presenting the higher demand especially in regard to heating.

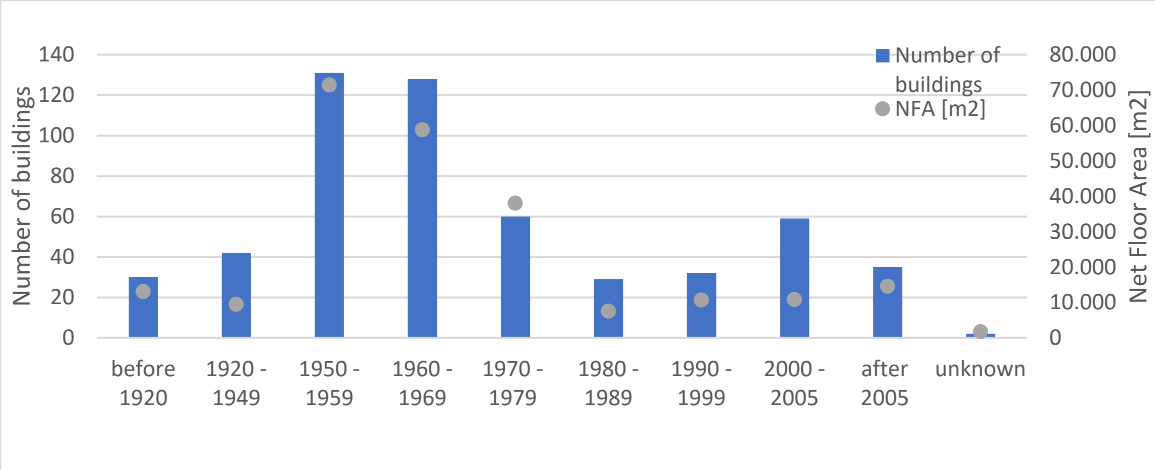


Figure 3-6. Residential buildings separated by year of construction [48]

The energy demand distribution might suggest that many buildings constructed before 1920 up to the 1960s have already undergone some retrofitting or renovation, in contrast to buildings dating between 1970s and 1980s. The enforcement of the first German ordinance regarding heat performance in 1977, might partly explain why buildings coming after this date are increasingly more efficient [25]. Even though most of them still do not meet the energy standard expected for the year 2050, there is a debate in the area regarding the economic viability to enforce further renovations [25].

Nonetheless, there are several projects financed and developed through ISEK to renovate and redevelop many areas in Griesheim-Mitte. These projects have a very large scope, ranging from the train station renovations to house retrofitting and social spaces construction. They not only have the scope to improve the appearance of the district, but also to strengthen social life and people interaction on the everyday life. This all happens keeping citizen participation active, by involving the local residents in the decision-making process. It is planned to spend a total of 224 million euros on these projects, through public and private investments [26].

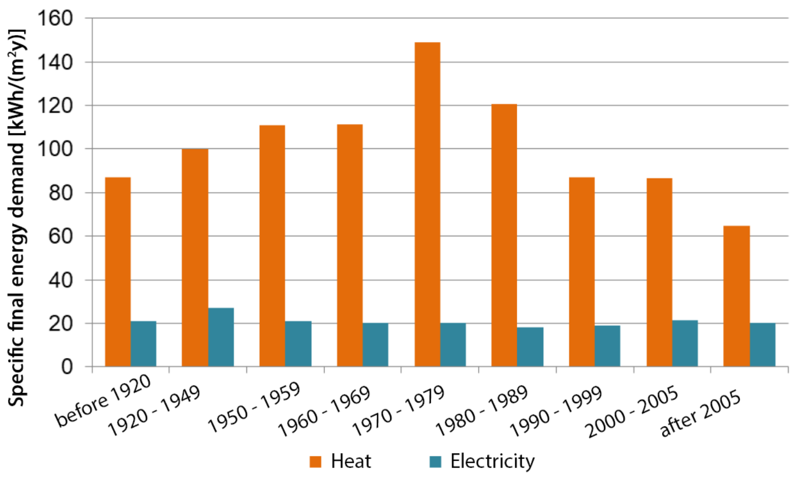


Figure 3-7. Energy demand by period of construction [25]

3.3 Energy System and relevant Stakeholders in Griesheim-Mitte

Four transmission system operators (TSOs) are responsible for planning and maintaining the high voltage network across Germany, balancing the national power supply and demand. TenneT TSO operates at the region of Frankfurt [37]. Germany has a liberalized retailing energy market, allowing customers to choose from a pool of providers, operating at national or local level (Stadtwerke) [38]. The latter often are involved in local generation. This is also the case in Frankfurt, where the local energy company "Stadtwerke Frankfurt am Main" is responsible for the supply of electricity, natural gas, heat and water as well as waste incineration. "Stadtwerke Frankfurt am Main" has two key subsidiaries, Mainova AG, which is responsible of energy, the local DSO and water network, and AVA, which deals with waste incineration. Mainova operates six Combined Heat and Power (CHP) plants and one CCHP (combined cooling, heat & power) plant[10] as well as a network of district heating in Frankfurt [39].

The city of Frankfurt covers 39% of the local power demand by local electricity generation sources (Figure 3-8), importing 61% from the main grid. From the locally generated power, the majority is fossil-fuel based, followed by waste incineration. Renewable generation is only 3% of the total, of which about 55% is based on biomass, 18% is associated with biogas digestion, 16% is hydro and 11% is photovoltaic generation [40].

[10] the Federal government supports the investment in combined heat and power (CHP) and heat from renewable energy, such as solar thermal, biomass, and heat pump systems as potential solutions to achieve the decarbonisation targets at local level. The development and use of CHPs are regulated by the national Combined Heat and Power Act *(Kraft-Wärme-Kopplungsgesetz, KWKG),* which, among other matters, defines the amount and condition for surcharge received by CHP operators [242].

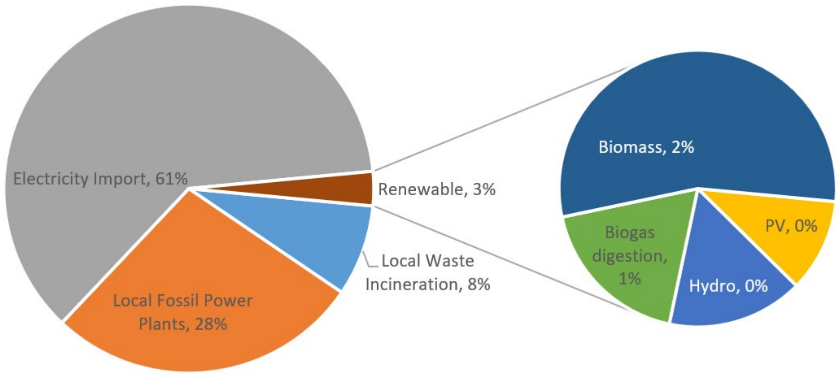
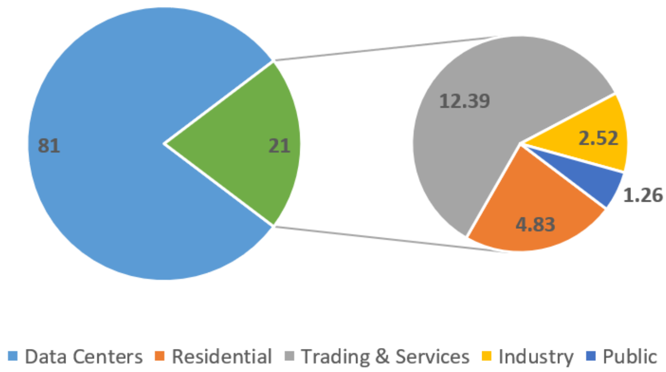


Figure 3-8. Share of local electricity generation in Frankfurt am Main city [40]

The annual energy consumption of Griesheim-Mitte (in 2017-18 terms) is approximated to 148 GWh, from which 46 GWh_{th} is used as heat and 102 GWh_e as electricity. This unusual distribution is due to the energy intensive data centres which alone require 81 GWh_{el} annually, around 79% of the total (Figure 3-9(a)). Figure 3-9(b) demonstrates the intensity of energy consumption by the Data Centres, while the residential buildings have a comparably low energy consumption in comparison to non-residentials (Table 3-1), with an average of 20 kWh/m^2 annually. The associated greenhouse gas (GHG) emissions of the district sum up to 71,500 tCO_{2_equ}, while a significant share of approximately 80% is associated to main-grid electricity. This accounts for 0.88% of whole Frankfurt a.M.'s GHG emissions [25].



(a)

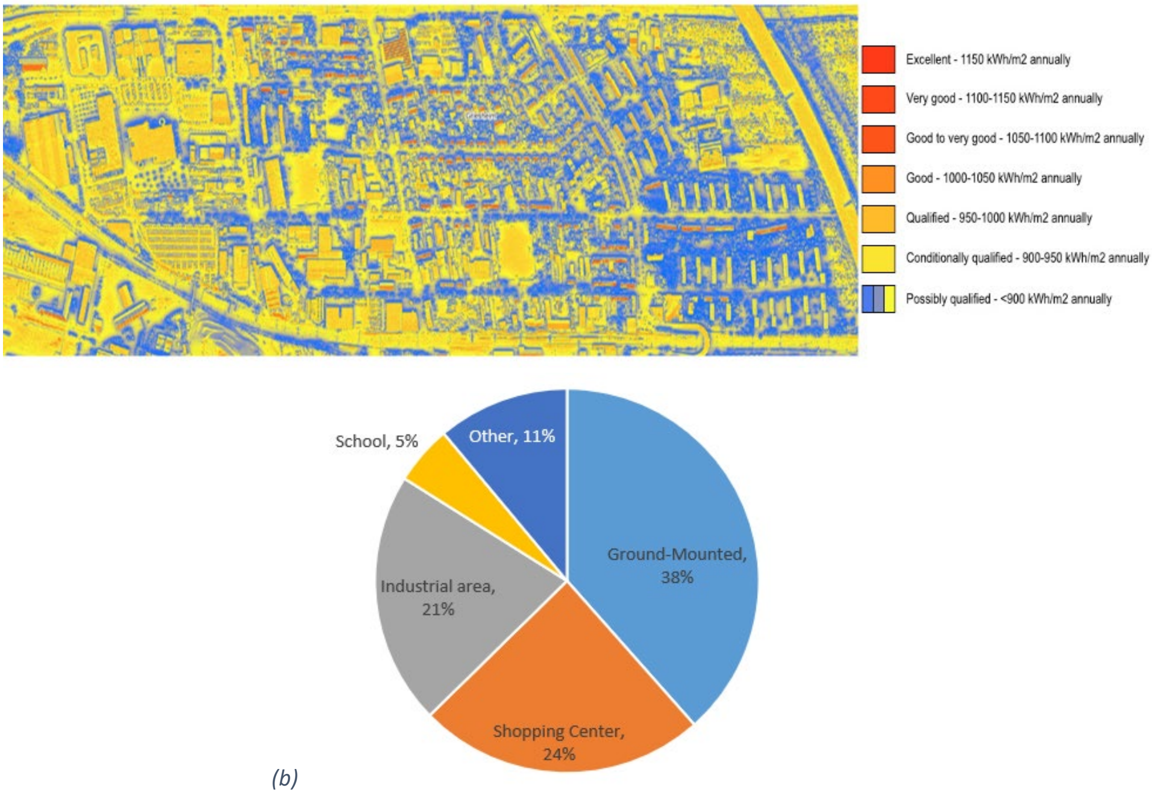
(b)

Figure 3-9. (a) Annual average electricity consumption by building usage in Griesheim-Mitte in GWh between 2017-2018 [48]; (b) Area-specific, annual electricity consumption by building block averaged from 2017-2018 in MWh/m^2 [25]

Table 3-1. Average electricity consumption of non-residential buildings [25]

Building Usage	Area [m^2]	Absolute Consumption [MWh/a]	Specific Consumption [kWh/m^2a]
Hotels, Motels & Pensions	5,144	445	87
Education and Childcare	21,420	755	35
Social Purpose	347	3	8
Offices	5,879	83	14
Trading and Services	125,542	10,928	87
Industry	68,524	2,339	34
Hospitality	2,684	545	203
Convention Buildings	5,106	389	76
Religion	2,419	41	17

Photovoltaic system installations are considered the most promising in the context of the city (Figure 3-10(a)). The installed capacity in Griesheim-Mitte sums up to around 442 kW_p in 14 PV installations across the city (Figure 3-10(b)) [25]. The Ebök report proposes that approximately 250,000 m^2 roof area could possibly be used for solar energy generation (either photovoltaic electricity or solar thermal heat generation), of which only around 3,400 m^2 are already occupied by one of the two technologies (Table 3-2) [25].The 21.1 GWh of annual potential PV power generation could satisfy the district wide electricity demand for residential use over the year (assuming that considerable storage capacity will be also installed).



(a)

(b)

Figure 3-10. (a) Solar PV Potential on roof and open areas in Griesheim-Mitte [41]; (b) PV Capacity installations in Griesheim-Mitte

In Frankfurt there are a variety of options for those who want to have PV panels. There are various ownership models offered in the market, such as a PV-leasing model by Mainova AG and citizen solar initiatives by Solarinitiative e.V. and Solarverein Frankfurt [42]. As long as they supply those who live in the same place (i.e. building) or in the close proximity to an installed PV system, they can benefit from the special surcharge for powering the tenants (*"Mieterstromzuschlag")* from the Renewable Energy Act 2017 [43]. For appliances that derive heat from renewable sources, Renewable Energy Heat Act *(Erneuerbare-Energien-Wärmegesetz, EEWärmeG)* sets the regulatory boundaries and determines the eligibility for a subvention [44].

Table 3-2. Estimation of applicable rooftop area in Griesheim-Mitte for PV power generation [25]

Dwelling Usage	Applicable gross roof area	Already occupied		Potential PV area	Potential PV-electricity generation
[-]	[m²]	[m²]	%	[m²]	[MWh/a]
Residential	71,800	510	0.7	51,000	7,100
Trading and Services	87,400	460	0.5	47,600	6,800
Public	17,100	840	4.9	9,100	1,300
Industrial	59,500	1,550	2.6	34,200	4,900
Others	13,600	40	0.3	7,400	1,000
Sum	249,400	3,400	1.4	149,300	21,100

The main energy source for the supply of heating in Griesheim is natural gas. There is no District Heating infrastructure in place currently, although the closest one in place is only few kilometres away. The gas network provides to about 500 buildings covering 78% of the residential buildings and three-quarters of the whole building stock. During 2017-2018, the gas consumption averaged to 35 GWh annually[11], of which 63% in residential buildings, 19% retail and services, 8% trade and industry and 10% in public buildings. The Hessian State Office for Nature Conservation, Environment and Geology defines the area as "hydrogeologically unfavourable". Although this does not imply it is impossible to utilise shallow geothermal for heating, it does suggest higher difficulties and complications in placing and operating geothermal probes [25]. The Ebök's report investigated the potential use of shallow geothermal to supply heat to a hypothetical district heating network. A parallel study demonstrated furthermore, that the data centre that operates in the district might be a potential source to supply around 12MW[12] into the district heating network [25], covering partly the needs of the district.

3.4 Mobility and the Transition to Sustainable Mobility in Frankfurt

Transport is a major contributor to the total CO_2-emissions in the city of Frankfurt, contributing 1.67 million tons in 2017, without considering the Airport[13]. The majority of those emissions come from the commuters' private transport [32]. Frankfurt's measures in the past to improve its mobility

[11] The gas consumption is weather-adjusted and does not distinguish between Space Heating (SH), Domestic Hot Water (DHW) and cooking. Both DHW and food preparation are impossible to separate from the total consumption, although the latter is usually negligible. Furthermore, some of the buildings might employ different ways to generate domestic hot water (e.g. electric heaters, heat pumps, etc.). Only 11 buildings are known to utilise air to air/water heat pumps, although there might be more [25].
[12] The centre requires 8 MW of constant cooling, for an estimated waste heat of approximately 70 GWh yearly. The waste heat is generated at low temperature, needing a temperature boost to bring it to a more suitable temperature to be utilised as Space Heating in residential units. Assuming a COP of 3.0, it would be possible to generate about 12 MW to be supplied to a district heating
[13] The Airport added further 850 000 tons [243]

concept, such as those within "Frankfurt e-mobility 2025" program, Bike+Ride, Bike+Business, have helped to develop SM in the region [45]. As of June 2020, there is no separate mobility strategy, but it is one of the building blocks of the current Masterplan [32]. Moreover, there is a plan to have a regional mobility plan by 2021 [46].

The high number of daily commuters (ca. 280.000 in 2018 from the Main metropolitan area alone, Figure 3-11(a) create a discrepancy between the residents and the daily population of the city regarding their mobility choice. Around half of the residents choose walking or cycling for their daily journeys, while amongst the daily population (residents + commuter balance) the share is only 38 % (Figure 3-11(b)) [47]. Around one-quarter of the residents use public transportation, while only around one-fifth of the daily population choose this [47]. As for private motorised transport, one-fifth of the residents and one-third of the daily population depend on it [47].

3.4.1 Active modes of transport

As a result of the urban planning strategy for "short trips", around 30 % of Frankfurt's citizens cover their daily trips by travelling on foot [32]. This is one of the highest shares within the European Union [32]. The city has already pushed the agenda to increase the number of trips by foot further by considering the needs of pedestrians in terms of urban planning. For example, Frankfurt implemented 30 km/h speed zones in almost all residential areas and wants to introduce them further on main transport zones in order to raise the attractiveness of this choice of active transport [32].

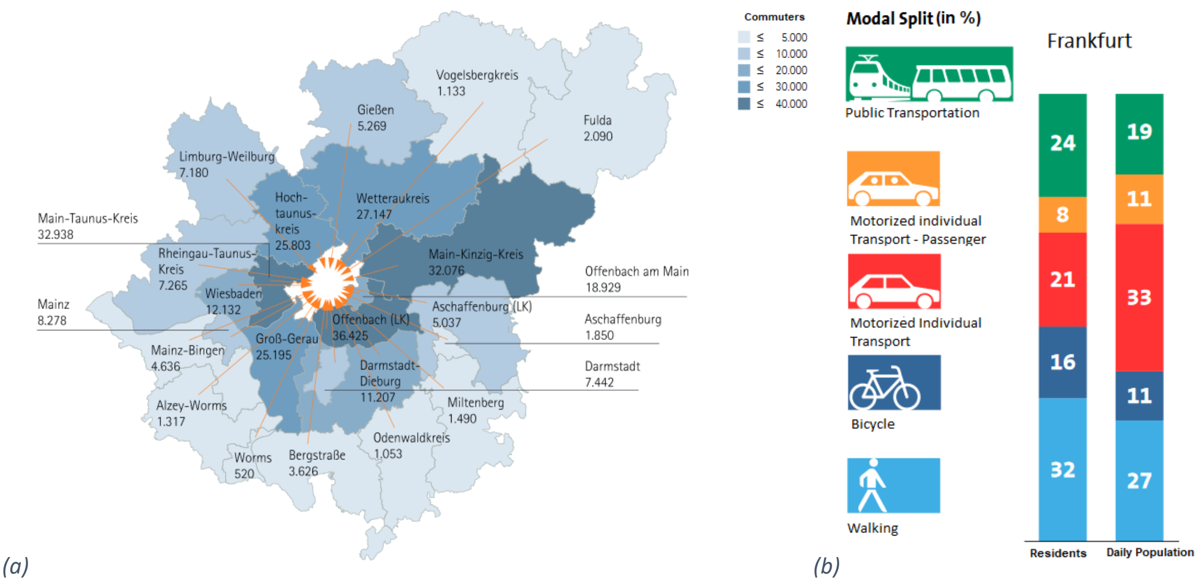


Figure 3-11. (a) Number of daily commuters of the Main metropolitan area to the city of Frankfurt in 2018; (b) Modal Split in percentage in Frankfurt in 2017, in percent [47]

The promotion of cycling as an attractive choice of transportation is another focus of the government. Only 16 % of trips are covered by bicycle and, compared to other European cities like Amsterdam or Copenhagen, is rather low. One possible improvement targets especially commuters, who should be attracted to switch from car to bicycle. Based on data from the Regional Authority Frankfurt RhineMain, approximately 130,000 to 140,000 commuters come from a catchment area of 5 to 15 km [32]. Therefore, implementing fast bicycle tracks could reduce traffic congestion. Furthermore, by combining it with further measures, such as feeders at local public transport stops or P+R car parks, the positive effect can even be stronger [32]. Additionally, commuters are encouraged to use electric bikes, i.e. Pedelecs [32]. For example, the initiative “bike+business”, which is based on a cooperation between the city and companies, aims to increase the use of pedelecs and conventional bicycles in commuter traffic. Partner companies, such as the Airport of Frankfurt, have to provide the infrastructure – changing rooms, showers and bike parking spaces – for their employees [32]. Furthermore, government subsidies for any type of electric bikes and to companies providing their own bikes to employees are planned in order to promote this mode of transport [32].

Installing bike stations at local public transport stops and better cooperation between bike lending schemes and local public transport targets Frankfurt citizens and tourists, who would be able to move around easier, faster and in an environmentally friendly fashion. Currently, two bike-lending operators exist: “Call a bike” (run by Deutsche bahn) and “Nextbikes” [32]. However, with respect to the large number of daily commuters, an inter-city lending scheme would also be beneficial. A cooperation with the city of Offenbach has already taken place, but other cities are to follow. Additionally, implementing traffic light circuits tailored to bike traffic and secure bike parking (biketowers) is also planned to increase the use of bicycles as the choice of transport.

As for the bike sharing station in Griesheim-Mitte, there are only 3 such stations in the whole of Griesheim (Figure 3-12). This is rather low number, when compared to the central parts of the city [48] and there is no further information about further expansion.

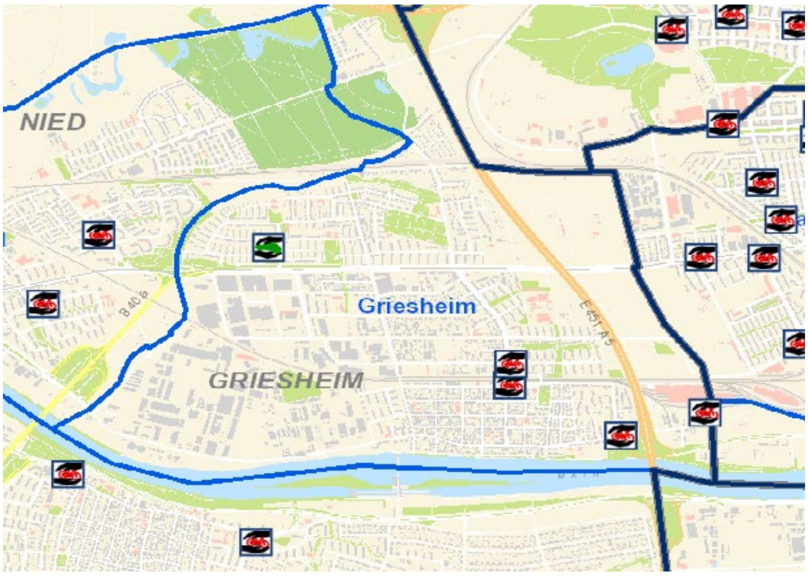


Figure 3-12. Charging stations, bike sharing stations and car sharing stations in Frankfurt Griesheim [48]

3.4.2 Public transport

The organisation and coordination of public transport in the city of Frankfurt is in the hands of the public transport association *traffiQ*. It is responsible for infrastructure planning, scheduling, customer communication, research, management of contracts, purchasing, finances, and many other services for the city [49]. The transport network, however, belongs to the Rhine/Main Regional Transport Association (Rhein-Main-Verkehrsbund) or *RMV*. It is one of the largest public transport associations in Germany, which also co-operates the public transport network in Frankfurt region, the Rhine-Main Metropolitan Region and other parts of the Federal state of Hesse [50]. The operators of different types of public transport are presented as follows:

- *Rapid transit*: Deutsche Bahn, the national German railroad operator.
- *Subway and trams*: city-owned Frankfurt Transit Company (Verkehrsgesellschaft Frankfurt)
- *Buses*: Verkehrsgesellschaft Frankfurt, In Der City Bus, MainMobil Frankfurt, Autobus Sippel, DB Regio Bus Mitte, Urberacher Omnibusbetrieb, and Transdev Alpina Rhein-Main [51].

Modal share of public transport among the citizens of Frankfurt is roughly 24% and slightly lower (19%) among the daily population (Figure 3-11(b)). The plan of the city is to reach 35% by 2050 [32]. In order to reach this ambitious goal, the city bus fleet is planned to run completely on electric energy and hydrogen fuel by 2030 [52]. The municipal bus operator In-der-City-Bus (ICB) and private operator Transdev Rhein-Main have ordered 11 and 13 electric buses respectively and the city should start deploying them from the end of 2020 [53] [52]. Moreover, 22 additional hydrogen-fuelled buses are going to be purchased by the ICB to be deployed starting from 2021 and 2022 [52]. Due to a shorter range, these busses can also be used as express buses, which stop only at high frequented bus stops to reduce traffic during rush hour.

In recent years, the city focused on ways to increase the attractiveness of public transportation by expanding the bus and rail networks and giving new city districts access to local public transport, such as new bus routs, tram- and city-rail lines [54]. For example, the new tramline 18 operates since 2011 and connects the new housing development on Frankfurter Bogen in the North of the city and the city centre. The project required also a completely remodelling Friedberger Landstraße, one of the city's main traffic arteries. As a result, car lanes were reduced and new cycle paths were built.

3.4.3 Motorised private transport (MPT)

With the commuter traffic included, Frankfurt has an MPT share of around 45% (Figure 3-11(b)). In order to reduce emissions, the current focus is on promoting electric cars [32]. The city wants to increase their acceptance by creating incentives, such as reduced parking fee for electric vehicles (and car sharing), both for companies and citizens. Furthermore, Frankfurt wants to provide the infrastructure needed to run an electric vehicle by implementing inner-city charging stations and parking for residents (i.e. multi-storey car parks and district garages), as well as by incentivising the investors in single-family and multi-family dwellings to include charging stations and parking spaces for e-vehicles in the planning [32]. Available charging stations in Frankfurt can be looked up in the GeoInformation-tool provided by the city. Figure 3-12 displays the EV charging points in Griesheim. The majority of the charging stations in Frankfurt are owned and operated by Mainova AG, Innogy e-mobility solutions (or RWE), APCOA Parking GmbH [55]. The charging station in Griesheim-Mitte is owned by Lidl GmbH. Mainova AG is further strengthening its position by building 20 fast-charging stations in 2020 and providing charging solutions in living quarters, communities and companies [56].

Car sharing (CS) is another solution to reduce emissions and the volume of city traffic. Currently, several CS providers, such as Car2Go, Book-n-drive Carsharing and Stadtmobil Carsharing, offer shared vehicles in over 300 stations in Frankfurt [36]. In order to increase the attractiveness for CS, the city of Frankfurt wants to increase the supply of parking spaces for CS vehicles. Right now, there are only 0.63 car sharing vehicles per 1,000 residents. Karlsruhe, with the highest rate nationwide, has a share of 1.63 vehicles. Furthermore, the study Fraunhofer IBP predicts that approximately 3,456 private cars can been replaced by 432 car sharing vehicles in Frankfurt [57]. There are 3 large car-sharing companies as of 2020: book-n-drive (mobilitätssysteme GmbH), Stadtmobil (Rhein-Main GmbH), and SHARE NOW (before car2go & DriveNow) [58]. They have also partnered with RMV and offer combined tickets with public transport [59]. However, the fleet of these companies consists of predominantly petrol-fuelled cars. As for pure e-carsharing companies, flinkster, a subsidiary of the Deutsche Bahn, has 3 stations in the city centre that provide e-carsharing services [60]. Moreover, a local start-up called mobileeee rents out cars at one location [61].

3.5 Concluding Remarks

Frankfurt municipality set ambitious goals against climate change – to reduce its GHG emission by 95% and halve the primary energy consumption by 2050 compared with 1990 levels. To achieve this, the city is putting significant efforts towards energy efficient building stock, sustainable transport and citizens' social inclusion through participative planning. Especially evident is the focus of the city in the improvement and decrabonisation of neighbourhoods, such as Griesheim-Mitte.

Griesheim-Mitte, formerly an area of an industrial character, is rigorously supported by several municipal and regional programmes that bring the district in a new pathway of sustainable development. On the one hand, renovations of buildings and infrastructure in the district are bringing a new look and energy conservation in the district. Considerable potential for PV, solar thermal and renewable district heating in the form of process waste heat from the local data centres has been studied and waiting to be exploited to the benefit of all in Griesheim-Mitte. On the other hand, engaging the residents in the planning process of the redevelopment in Griesheim-Mitte not only creates a place where people can interact and create communal-led initiatives, but also ensures the social inclusion of all groups active in the district. These activities are facilitated by the Neighbourhood management office on behalf of the local government.

In relation to the dimensions studied within this work, the framework conditions for developing PEDs in Griesheim-Mitte can be summarized with the following diagram (Figure 3-13).

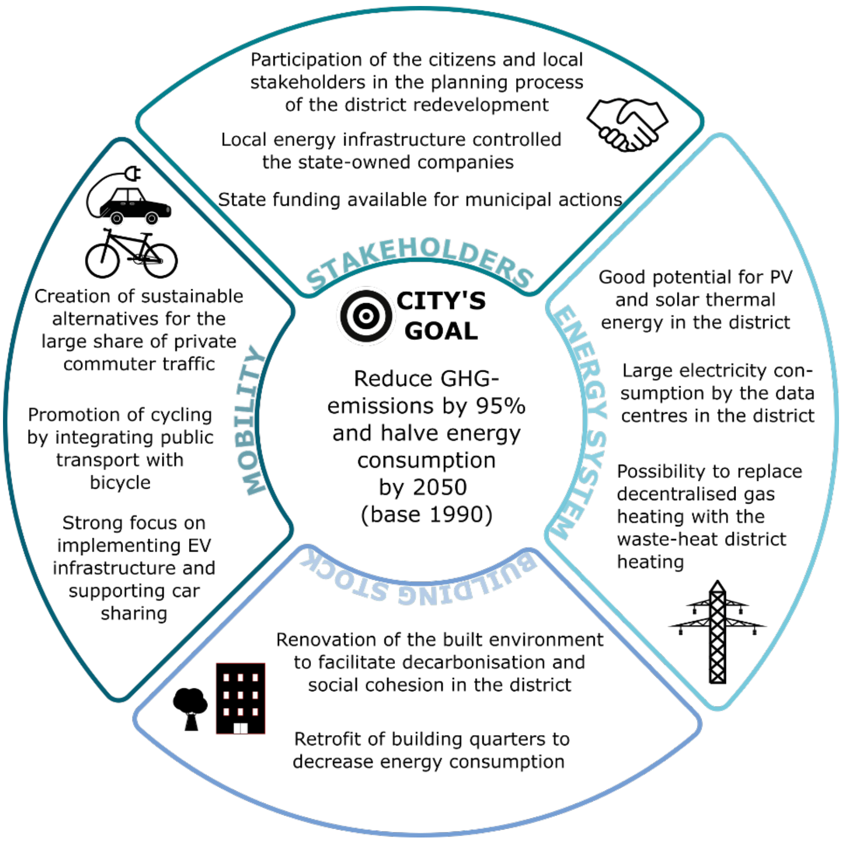


Figure 3-13. Summary of the framework conditions for establishing PEDs with respect to the analysed dimensions – Frankfurt: Griesheim-Mitte

4 The Case of Nottingham City

Case ID: Nottingham City

Nottingham is a city located within the non-metropolitan county of Nottinghamshire, in the East Midlands region of England. Nottingham received unitary authority status in 1996 [62], meaning that the City is now governed fully by its own City Council. The County of Nottinghamshire is divided in 7 boroughs (district councils) [63], with powers and functions shared between the County Council and District Councils [62]. The population of the City is estimated to be about 332,900, with 67.7% being working age people [64]. Nottingham is renowned for its public transport, recognised as one of the best systems in the UK, as well as for its literature, sports, lace-making heritage, and universities.

Nottingham City has 3 localities (North, Central and South), with the city centre being split between Central and South localities (Figure 4-1). For administrative purposes, Nottingham City is divided into 20 electoral wards [65]. The City centre consists of several quarters, known as Canal Quarter, Castle Quarter, Royal Quarter and Creative Quarter. Moreover, various neighbourhoods can be identified from the GIS system of the NCC, for example St. Ann's, the Park, the Meadows, Sneinton, Lenton, Radford and Forest fields [66]. The study focuses on the City as a whole, which, for policy purposes, is treated as a single location.

Key priorities: Sustainable transport and elimination of fuel poverty

Key achievements:

- Construction of the new tram line, bike lanes and support for EVs;
- Improvement of the social housing stock;
- Support and awareness-raising campaings for residents.

Key challenges: relatively high carbon emissions from transport sector

Figure 4-1. Boundaries of Nottingham City [67]

4.1 Policy Framework and Policy Stakeholders in Nottingham

Decision making authority in Nottingham City lies with the Nottingham City Council (NCC). It consists of 55 Councillors elected by citizens in the city's 20 electoral wards. Thus, 2-3 councillors represent each ward and hold regular surgeries, where citizens can come to ask for information or advice, to express an opinion, make a suggestion, etc [68].

Since the launch of the Nottingham Declaration in 2000, signed by more than 300 English municipality councils committed to address the causes of the climate change, Nottingham City has been strongly proactive in tackling climate change [69]. The aim of the most recent strategy ***"NCC Energy Strategy 2010-2020"***, which aimed to reduce the CO_2 emissions by 26% compared to 2005 by 2020, was achieved and exceeded earlier than planned. The most recent data, from 2017, show a reduction of 41% [70] [71]. The second target – to produce 20 % of energy within the Greater Nottingham area from renewable or low/zero carbon sources – is purportedly on track [71].

For the upcoming years, Nottingham City has prepared the action plan ***Carbon Neutral Nottingham 2020 – 2028***, which is based on Nottingham's Carbon Neutral Charter [71] [72]. The overarching goal is to become the first carbon neutral city in the country by 2028. In addition, a sector-specific Local Transport Plan, Energy Strategy, and Resilience and Climate Strategy are under preparation [72]. The current and planned programmes for decarbonisation are categorised into five sections - transport, built environment, energy generation, consumption, waste and water [71]. Of these five policy areas, three are of particular interest within the scope of this report. The planned and ongoing actions in these three areas are summarised in Figure 4-2. No quantitative targets for each sector have been defined at this stage.

Buildings

- increasing the energy efficiency by encouraging energy-efficient standards, technologies and behaviour
- minimising emissions in construction
- switching to low-carbon or renewable heating

Transport

- reducing travel need
- switching to more sustainable modes of transportation (walking, cycling, low carbon public & private vehicles)
- reducing the impact of freight transport
- improving the transport infrastructure for low-carbon transport
- traffic demand management

Energy generation

- creating a vision for the decarbonised energy system
- expanding local renewable an low-carbon generation and storage
- motivating the testing of new technologies in the city (e.g. by encouraging Living labs)
- making low carbon energy affordable and accessibile to all

Figure 4-2. The objectives of NCC in the Building, Transport and Energy generation sectors

Nottingham's actions in the field of transport are one of the most progressive in the UK. During the last decade there has been a 13% decrease in GHG-emissions since 2005 and overall transport energy demand sinked by 8.9% [50]. This is due to the solid policy formulation and securing the necessary funds for the planned measures. On 1 April 2011, the ***Nottingham Local Transport Plan (LTP)*** came into effect [73]. This is a a statutory document that presents the long term transport strategy and 3-year rolling investment programme (currently for the period of 2019-2022) [74]. The progress made is monitored and presented in the annual reports [75]. Many projects are being realised within this

Strategy with the anticipation that sustainable mobility in the city and the region will boost the economic activity of the area (e.g. due to tourist inflow, business uptake, job creation). One of the polices that are well-known is the above-mentioned Workplace Parking Levy.

Another area that is considered very essential is tackling of the fuel poverty in the households of Nottingham. The approach that NCC takes is governed by the current ***Fuel Poverty Strategy for 2018-2025*** [76]. The main goals are to “reduce energy bills, increase thermal comfort and well-being in the coldest and most vulnerable homes and to improve Nottingham City’s Fuel Poverty rate” [70]. The key actions include:

- reducing energy bills by encouraging and providing information on switching to a cheaper tariff or energy provider (e.g. non-profit utility company RobinHoodenergy) and introducing smart meters;
- improving energy efficiency via increasing awareness of household energy efficiency ratings EPCs among private renters, supporting the elimination of E, F and G EPC rated homes, and providing energy advise [77];
- maximising household incomes through support and communication of energy-related benefits, subsidies and grants.

Through this Strategy and Action Plan, Domestic Energy Efficiency Fuel Poverty subgroup (DEEFP) together with sister organisation Robin Hood Energy, Enviroenergy, Nottingham City Homes and Nottingham Energy Partnership, is taking care of affordable warmth and healthy homes for all citizens [71]. One of their tasks is to make citizens aware of the grants and subsidies by the Central Government, such as the Domestic Renewable Heat Incentive (RHI) and the Affordable Warmth Obligation [78]. The first program provides subsidies for homeowners based on the amount of renewable heat made by installed systems, such as biomass boilers, solar water heating, certain heat pumps. The latter assists homeowners and social house residents with the cost of insulation work or upgrades to heating systems in the form of tax benefits and help with installation.

Thus far, Nottingham’s policy activities have been nested within not only English and UK policy, but also EU policy. In the context of Brexit, this will change. As of 2019 the UK government has declared it will maintain its own ambitious climate and emissions goals, and to seek cooperation with EU in the areas of energy supply and security [79]. In the Climate Change Act 2008, the UK government made a legally-binding commitment to reduce GHG emissions by at least 80% by 2050 relative to 1990. In 2019 it raised this target to a (net) 100% reduction [79] [80]. To drive this, the following strategies have been put in place: the Clean Growth Strategy, the Industrial Strategy, and the 25 Year Environmental Plan [50].

For the 2017 Clean Growth Strategy, the UK Department for Business, Energy and Industrial Strategy (BEIS) provides funding for projects and initiatives in the key areas responsible for GHG emissions – buildings, transport, business and industry efficiency, power supply, natural resources, and others [81]. Nottingham City can access these funds through the ***Derby, Derbyshire, Nottingham and Nottinghamshire Local Enterprise Partnership (the D2N2 LEP)***, with £250million in the Local Growth Fund allocated to the D2N2 LEP to support local growth [82]. The money is to be used for co-investment in projects across the D2N2 area which create jobs, improve infrastructure and attract investments [59]. Current activities to enhance the Southside of Nottingham City have focused on residential, office, and public buildings [83].

Nottingham's longstanding position at the forefront of sustainable cities includes the Green Partnership, a 25-year old formal collaboration of public, private and voluntary organisations working towards making the city more sustainable. The flagship Carbon Neutral Charter 2028 is the product of this partnership's work and a pledge of their support in achieving such ambitious sustainability targets [84]. The cross-cutting nature of the Charter requires a wide range of partners. These include NCC, Severn Trent Waters, Nottingham Trent University, the University of Nottingham, Nottingham Energy Partnership and others [85]. Moreover, the Partnership is establishing a participatory structure, involving citizens, businesses, researchers and city officials in each of six key areas: Energy, Food, Mobility, Resources, Resilience, Biodiversity & Natural Capital. This offers the scope for Nottingham to develop a sustainability living Lab [72].

The climate and energy policy pathway of Nottingham City is displayed in Figure 4-3.

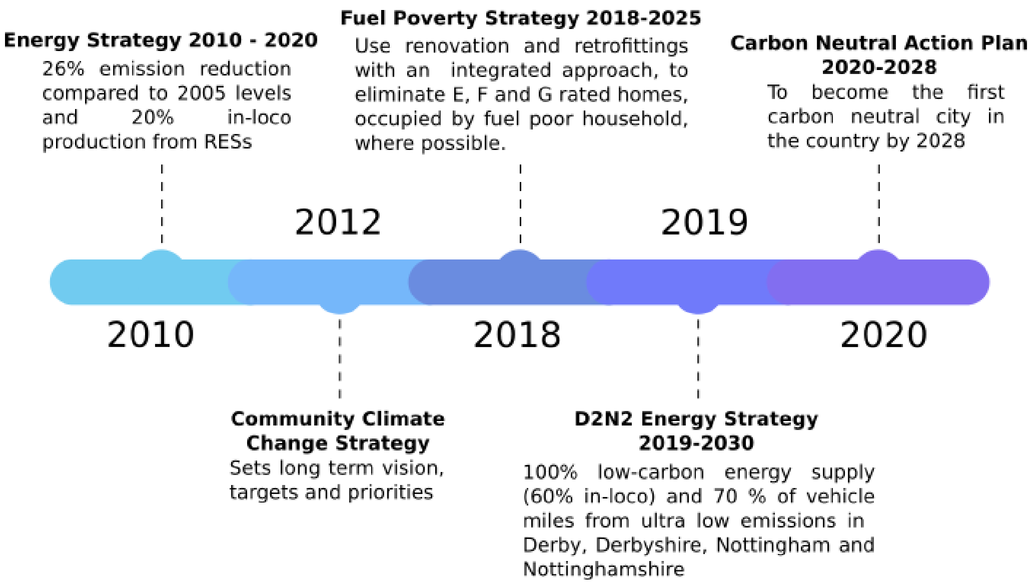


Figure 4-3. The climate and policy pathway of Nottingham City

After the financial crisis in 2008, austerity-driven public spending cuts had a dramatic impact on central-government funding of local government. At this same time, the 2008 Climate Change Act did not provide details of funding for local authorities [51] [56] [57]. As a result, local authorities have had to find new and innovative ways to fund climate-related actions. Nottingham City Council pioneered a new source of funding: the workplace parking levy (WPL) [57] [64], which is a charge on employers who provide workplace parking. The money raised is used for major transport infrastructure initiatives, such as the tram system extension, which introduced two new lines, the redevelopment of Nottingham Station, and an increase in bus network capacity [64]. Other financing streams have included the Area Capital Fund (ACF) for improving neighbourhood footpaths, investment in revenue funded programmes, funding secured through the Development Plan (the plan that guides the future development of the City), and funding awarded to partner organisations [65]. Further examples of funding the public transport measures can be found in [86].

4.2 Building Stock Condition in Nottingham

Nottingham City Council is very active in future proofing the current building stock, to align it to possible future requirements. The city is active on several fronts, performing renovation where possible, utilising some the current available tools such as Energiesprong (see Glossary) and other

European initiatives (REMOURBAN) [87]. In 2015, NCC commissioned a study to perform simulations and analysis of the current building stock in Nottingham. The study focused on residential buildings, leaving out businesses and industry. The information for the present report about the building stock condition in Nottingham comes from simulations and estimations performed in 2015 as a part of the "InSmart" project.

In Figure 4-4, a distribution of the different typology of dwellings is shown both for number and estimated total floor area. The predominant type of home is interwar semi/terrace house. On the other hand, interwar detached homes have the largest estimated total floor area. Heating demand varies considerably over the typology of buildings considered, ranging from 75 kWh/m^2 to 225 kWh/m^2 [88].

As might be expected, data from InSmart [40] indicate that older properties have higher specific heat consumption, almost double that of new apartments. The houses with the largest specific estimated consumption are Victorian terraced houses with 3 storeys, and Victorian detached houses of 100 m^2 or more. These types of housing are estimated to require around 225 kWh/m^2 of final energy in heating [88]. In comparison, the lowest specific consumption is achieved by apartments of the 1960s and 1970s with one wall exposed, and modern apartments with a floor area of 45 m^2 and two exposed walls, each type requiring approximately 75 kWh/m^2.

NCC is actively trying to improve the energy efficiency of its social housing through the Energiesprong initiative. NCC aims to renovate 155 homes in Nottingham. Two pilot schemes have already completed the renovation of 15 homes in 2017 and 17 homes in 2019 [89]. This scheme aims not only to reduce energy consumption, but also reduce annual maintenance costs and enhance the quality life of the residents.

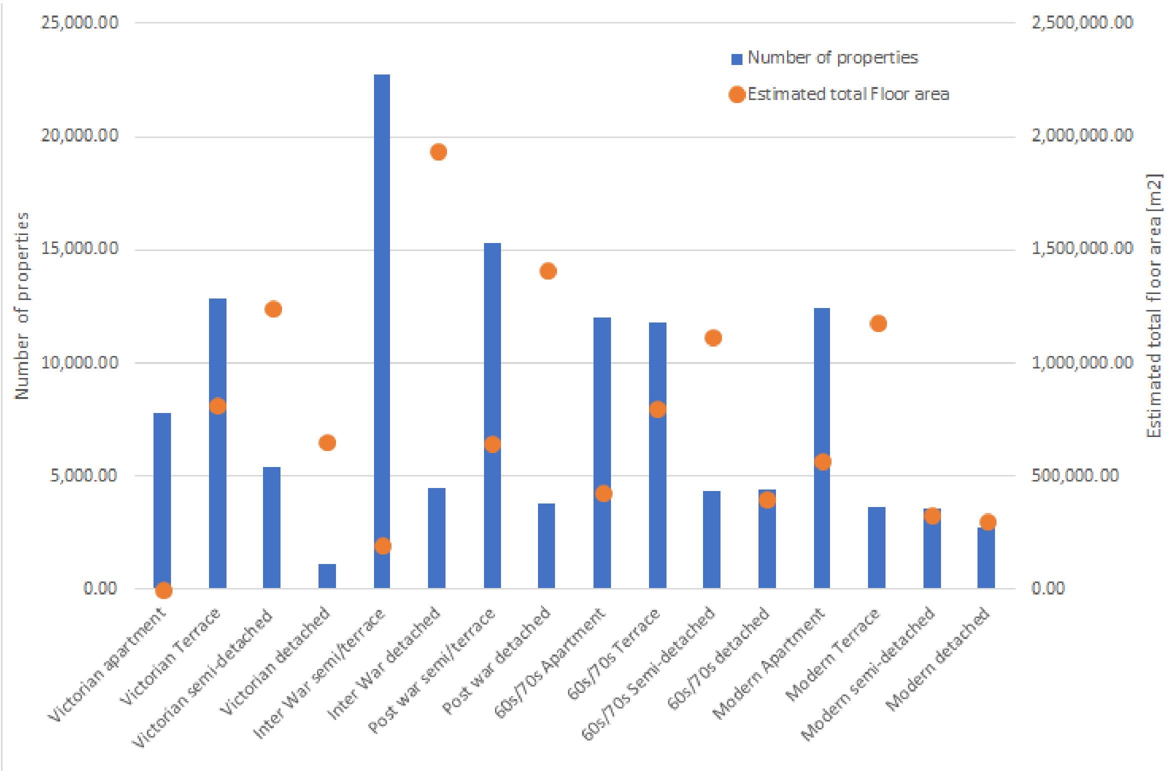


Figure 4-4. Residential units by typology in Nottingham [88]

4.3 Energy System and Relevant Stakeholders in Nottingham

No information regarding the region specific electricity mix could be obtained. Therefore the evolution of the electricity mix at the national level since 1995 is shown Figure 4-5. Here, the transformation away from coal and oil towards a more diverse electricity mix including renewables can be observed. Additionally, a general trend of decreased production is evident over time. Fuels within the category "Other" include among others, gas and chemical waste products as well as other renewables [90].

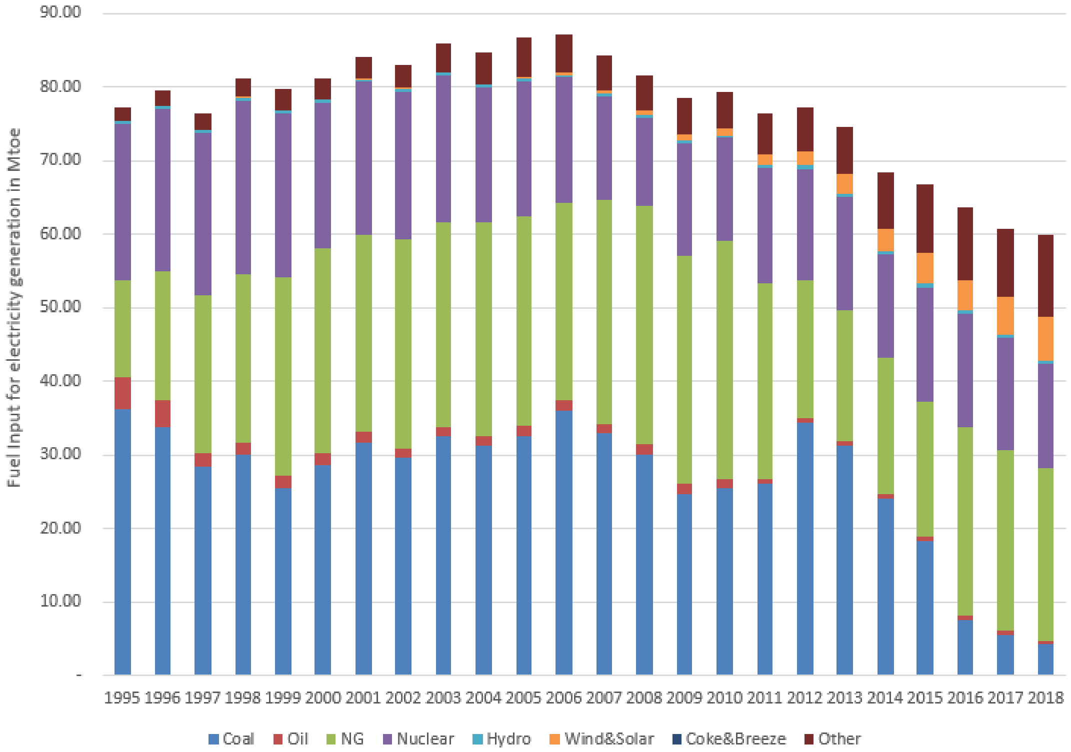


Figure 4-5. UK electricity mix by fuel input [90]

Figure 4-6 and Figure 4-7 show Nottingham's final energy consumption by energy vector and end user, respectively, (data from the Department for Business, Energy and Industrial Strategy). Both graphs show an overall reduction in energy consumption since 2005 [91].

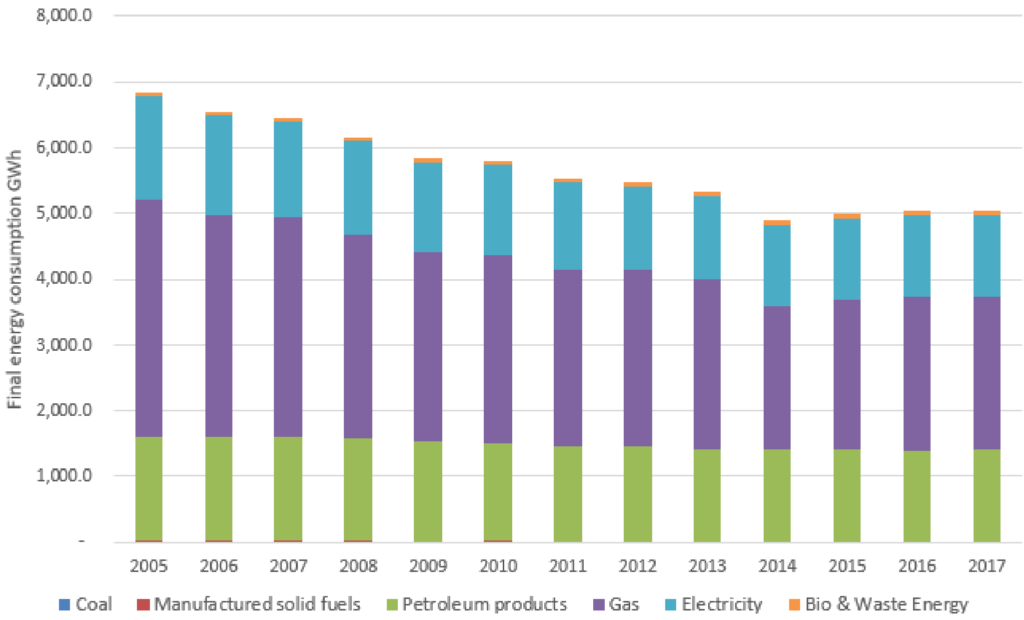


Figure 4-6. Nottingham's final energy consumption by energy vector from 2005 to 2017 [91]

Figure 4-6 shows a clear dominance of oil, gas and electricity in the energy consumption mix in Nottingham. In 2017, 89% of petroleum consumption was associated with road transport, while gas consumption is distributed approximately 2/3 residential and 1/3 industrial and commercial. In terms of electricity consumption this relationship is approximately reversed. Coal and manufactured solid fuels are used almost entirely by the domestic sector, but in such low volumes that they are scarcely detectable on the graph. The overall 26% reduction in energy consumption was driven mainly by a 35% reduction in gas usage, followed by a 22% reduction in electricity consumption, but only a 12% reduction of petroleum products from 2005 to 2017 [91]. No data are available to explain the consumption decrease. However, given that 2/3 of the gas usage is domestic and the reduction in gas consumption is the strongest contributor to the overall reduction, it is very likely that domestic efficiency improvements and/or heating technology change such as the penetration of district heating played a significant role. The enhancements made to Nottingham's publicly-owned housing stock will also help in reducing overall demand. Even so, by 2017 gas remained the single largest source of energy consumption.

Figure 4-7 illustrates Nottingham's final energy consumption evolution by end user. In 2017, the domestic sector and the industrial and commercial sector were responsible for similar shares of the final energy consumption with 39% and 36% respectively, while transport accounted for 25%. The main contributor for the consumption reduction in Nottingham is the industrial and commercial sector, with a 37% reduction over the period, followed by a 25% reduction of domestic consumption, but only 10% in transport [91].

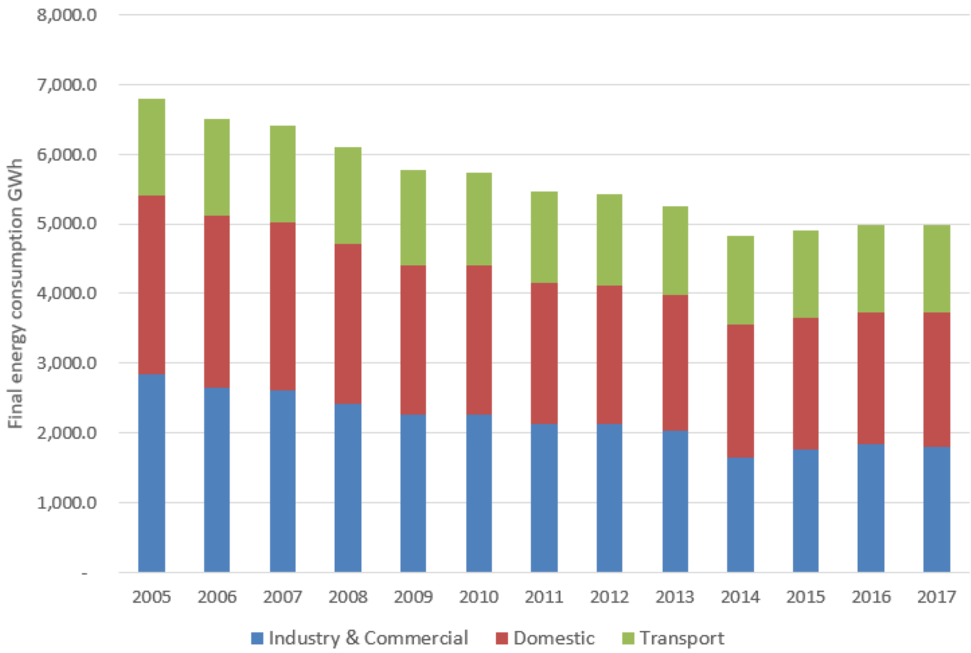


Figure 4-7. Nottingham's final energy consumption by end consumer from 2005 to 2017 [91]

In 2016, the distributed generation capacity within the East Midland Region, within which Nottingham is located, summed up to 3,064 MVA and including yet planned connections to 7,372 MVA, of which 31% is accounted for by solar PV, followed by wind and storage with 11% and 8%, respectively [92].

Regarding the city's carbon dioxide emissions, the trend is closely related to the energy consumption shown in Figure 4-8. The overall emission reduction of 41% over 2005-2017 is driven by a decrease of 56% by the industrial and commercial sector, followed by the domestic and transport sector with 38% and 13% respectively. In the commercial, industrial and domestic sectors the emissions are mainly a result of falling gas consumption, followed by electricity utilisation. In 2017, emissions per capita in Nottingham were relatively small with 3.6 kt CO_2 compared to a national average of 5.3 [93].

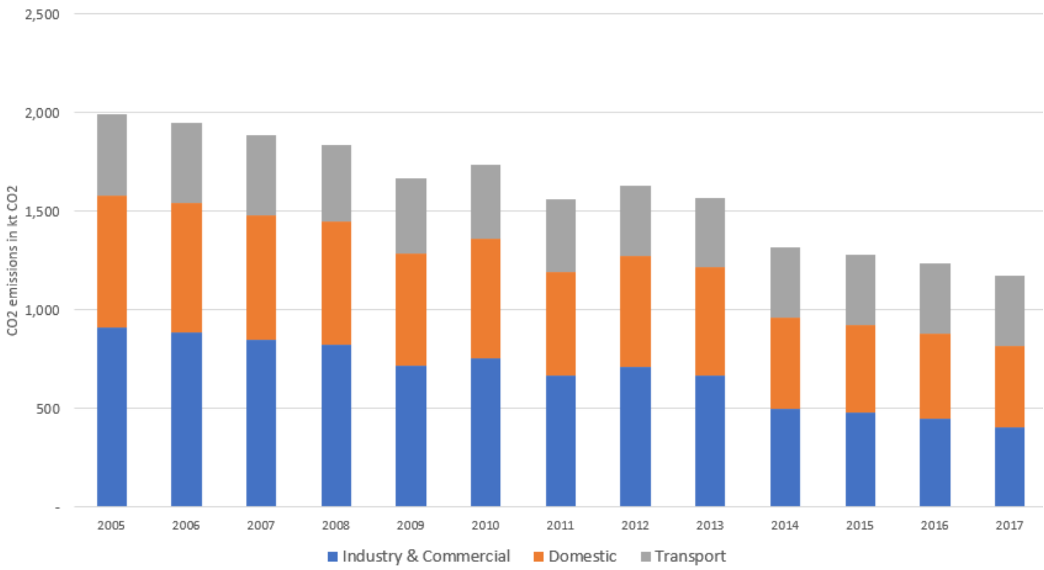


Figure 4-8. Nottingham's CO_2 emissions by end consumer from 2005 to 2017 [93]

The city is home to the largest District Heating (DH) Network in the UK. The network, operated by EnviroEnergy, a company wholly-owned by NCC, supplies heat to over 5000 homes and over 100 commercial customers, including Nottingham Trent University [94] [50]. The heat is produced at the Eastcroft Waste to Energy Power Plant, owned and operated by FCC Environment, burning 160,000t of municipal refuse annually. The Eastcroft Combined Heat and Power (CHP) plant produces 144 GWh heat and 60 GWh electricity annually. It is also equipped with an additional gas boiler unit to provide back-up heat when needed [94]. In total it is estimated that the DH system offsets 27,000 tonnes of carbon dioxide each year [95]. In addition to Eastcroft, there are also plans for Uniper to replace the current Ratcliffe-on-Soar coal power plant (18km outside Nottingham) with an incinerator, though the plans have still to be approved [96].

Following, some of the innovative projects that Nottingham is part of or initiated are showcased.

Since 2018, Nottingham has joined the D2Grids project, a European Union funded initiative to transition older district heating networks into low temperature. Thanks to REMOURBAN and through municipality-owned companies, a small low temperature district heating island has already been established. The return water from the main district heating (60-65 °C) is used as low temperature supply in the area, where buildings have been renovated to meet new heating requirements [87].

A second example of innovation is the SCENe (Sustainable Communities Energy Networks) energy neighbourhood project at Trent Basin [97]. This multi-energy vector project is run by multiple stakeholders, led by the University of Nottingham. It is a brownfield project consisting of 33 low-energy dwellings, equipped with 350 kWp solar PV installed capacity and a 2.1 MWh Tesla community-battery bank. For heating, ground source heat pumps and community thermal storage are planned. The project claims to function on a subsidy-free ESCO (Energy Service Company) business model [98] [99] [97] [100].

Further, Nottingham City Homes has equipped 4,000 of their properties with PV power [101], as well as installations in sport and shopping centres, in addition to what is possible regarding private PV rooftop installation. There is thus significant experience with distributed electricity generation in the city area [101].

The high voltage transmission of electricity in the England and Wales is carried out by two separate companies: (1) the National Grid Electricity Transmission (ET), which is responsible for the planning and maintenance of power related infrastructure, such as high voltage lines, and (2) the National Grid Electricity System Operator (ESO) that is responsible for the operation and balancing of supply and demand. Although both companies are under the National Grid Group, the ESO is operating for the whole UK while the ET operates only in England and Wales [102] [103]. The distribution network operator (DNO) of Nottingham is the Western Power Distribution, working within the East Midlands subsection. The DNO is the connecting agent between the high voltage transmission system and the various end consumers and is responsible for this connection [104].

Electricity suppliers purchase electricity on the wholesale market from centralized, large-scale generators and sell it to their customers. The UK’s liberalized energy market gives consumers a choice over their energy suppliers. In the case of small scale distributed generation, such as PV, the excess electricity fed into the grid has been managed by a government set Feed-in Tariff (FiT) from 2010 to April 2019. After the closure of the FiT scheme, since January 2020 the Smart Export Guarantee (SEG) has been established. It requires licensed suppliers to set a tariff and compensate prosumers for low carbon generation. The same rules as for the FiT scheme apply in terms of eligibility of technology. Solar PV, wind, hydro and anaerobic digestion qualify up to 5 MW and micro CHP up to 50 kW, which increased from the 2 kW established in the previous FiT scheme [105] [106] [107]. Other business models for prosumers are under investigation within academia [108].

It has to be noted that Robin Hood Energy went recently banktrupt when in 2019 accumulated debts by over 34 million British pounds and Its customers were sold to British Gas [109]. Therefore the organisational structure and plans to tackle energy poverty might suffer substantial changes in the near future.

4.4 Mobility and the Transition to Sustainable Mobility in Nottingham

Despite the relatively modest reductions in emissions so far, Nottingham's actions in the field of **transport** are amongst the most progressive in the UK. Indeed, globally transport is the one area of activity where emissions have continued to rise – a clear demonstration of the challenges governments at all levels face as they attempt to decarbonise and make more sustainable mobility systems [110]. We focus below on efforts to decarbonise mobility directly, but Nottingham is also addressing this in other, complementary ways. For example, it is encouraging and providing conditions for home working (e.g. video conferencing, shared hubs), as well as ensuring that new developments in the City are within easy reach (such as via access to public transport and cycle routes) [71].

The WPL has impacted car-use, in addition to raising significant funds that have been used to develop ever-greener public transport options. Solid policy formulation, such as the 2011 Local Transport Plan (LTP)[137], helped to secure additional funds for the planned measures. On 1 April 2011, the Nottingham Local Transport Plan (LTP) came into effect [73]. The LTP is a statutory document that presents the long term transport strategy and 3-year rolling investment programme (currently for the period of 2019-2022) [74]. The progress made is monitored and presented in annual reports [75]. Many projects are being realised within this Strategy, with the anticipation that sustainable mobility in the city and the region will boost the economic activity of the area (e.g. through increased tourist inflow, business uptake and job creation).

The most visible activities in Nottingham have been focused on the public transport system. The construction of two new tram lines in recent years (Nottingham Express Transit NET Phase Two), combined with the WPL, has resulted in 9.7 million additional public transport journeys per annum [71]. But another feature of Nottingham's work on mobility and emissions has been to make significant changes over time in the vehicles themselves. Initially, NET ran one line with 15 Incentro AT6/5 trams, built by Bombardier Transportation (formerly Adtranz), which were all refurbished between 2008-2014 [111]. NET Phase Two was accompanied by the purchase of 22 new Alstom Citadis 302 trams [112]. These new trams (powered by 4x120 kW motors) require 4 times less energy compared to standard buses and up to 98% of their parts are recyclable [113]. NET Phase also saw the tram system integrated physically with the railway station, creating Nottingham Station Hub.

The NET and railway station are location or narrowly route-specific; the most widespread changes have been in terms of the bus network. This has included integrated tickets covering both of the main bus operators (Nottingham City Transport, NCT, and trentbarton) with the tram network and local rail services. As with the trams, perhaps the biggest changes have been to the buses themselves. NCC only oversees directly the "Link" routes, not commercially-viable but which connect communities within and beyond the city boundaries, including the city's hospitals. There are currently 58 electric buses, operated on behalf of NCC by CT4N [114], making this the largest electric bus fleet in Europe in 2014 [115]. Trentbarton operate services into the city from neighbouring cities, towns and rural areas. Their actions include the recent purchase of 15 Alexander Dennis Enviro200 buses, which have "less emissions than a new car" [116] [117].

The largest operator within the city is NCT, with 310 buses. It is retrofitting 185 diesel buses with technology that reduces the fleet's tailpipe emissions by 90%. In addition, in the last two years (post-dating the earlier national statistics), NCT has introduced 120 biogas-fuelled double-deck buses, the largest such fleet in the world. These reduce CO_2 emissions by up to 84% compared with a brand new diesel-powered equivalent [118]. This is linked to Nottingham's anaerobic digestion plant mentioned earlier. They are not physically connected directly, because the installation of a pipeline from the AD plant to the bus depot would have been too costly and the construction work would itself have had environmental impacts. Instead the AD plant supplies, and the bus company takes out, equivalent volumes of biogas from the grid. In short, NCC is not only promoting public transport, but particularly green forms of public transport, through investment in cutting-edge mobility technologies.

Second, NCC is also active in promoting ultra-low emissions from motor vehicles for private and commercial activity. In particular, Go Ultra-Low Nottingham [119], a scheme supported by the UK government's Office for Low Emissions Vehicles, is seeing NCC not only encouraging taxi firms and private individuals to switch to electric vehicles (Figure 4-9), NCC is itself leading by example, adding EVs to its own fleet, including refuse lorries and street sweepers.

Third, there is active travel, in particular walking and cycling, but also including micromobility modes such as e-scooters [120]. Cycle lanes to key employment sites have been created or improved, including recently completed paths on Farnborough Road, Clifton Lane and along the canal in Nottingham [121]. Finances for the second phase were secured at the start of 2020 and cycle lane enhancements along key routes to additional employment sites (including cycle lanes along Slack Lane, Raynesway, and Nottingham Road), strategic cycling route from Derby to Nottingham along the former Spondon Canal, and support for new e-Bike hire in Nottingham are planned [122] [121].

In addition to infrastructure development, NCC provides grants for employers to encourage cycling among employees [123]. Up to £25,000 financial support is available for businesses and public organisations to make infrastructure improvements, such as cycle parking, showers, and pool bikes, but also electric vehicle charge points, car sharing and car parking management [123].

In sum, Nottingham is engaged in activities decarbonise public transport, private vehicles (personal and commercial) and promote active travel – the three key aspects of mobility in an inland city.

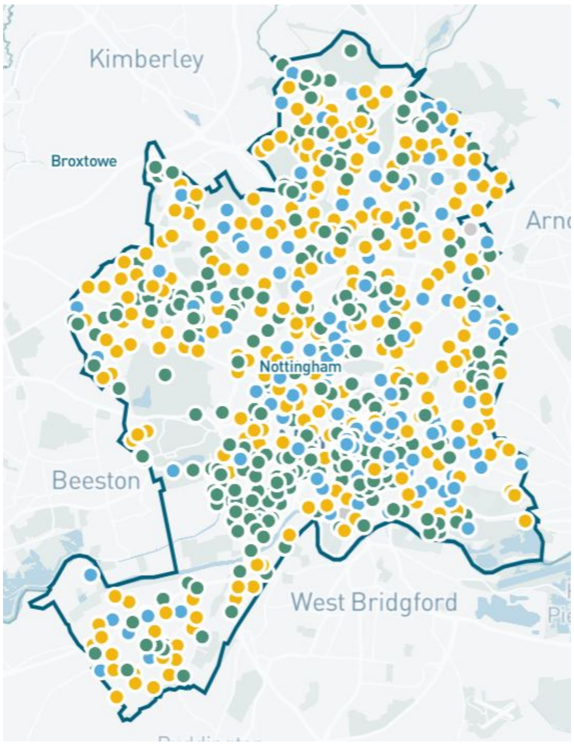


Figure 4-9. EV charging stations in Nottingham City (2020) [124]

4.5 Concluding Remarks

Nottingham City is one of the pioneers and most proactive municipalities in the UK when it comes to addressing climate problems on a local level, having set the goal of becoming the first carbon-neutral city in the UK. Nottingham City Council is taking the lead in actively promoting sustainability and decarbonisation – not only to contribute to global climate efforts, but also to boost the economic life and well-being of its citizens. But it recognises the need to work collaboratively, bringing together local and regional stakeholders and supporting the local sustainable initiatives.

As a result, within a short period of time (2005-2017), Nottingham reduced its energy consumption, notably in the domestic sector, where efforts have been directed towards making the social housing stock more energy efficient, and also in the commercial sector. A complementary measure in addressing energy poverty was the establishment of a not-for-profit energy company to provide renewable energy to residents at the lowest possible cost. On the production side of the energy system, the largest district heating network in the UK powered by municipal waste warms the city's homes and businesses. With the support of national policies, the share of renewable systems are rising in the region to provide everyone with clean electricity.

The most challenging part of decarbonisation in Nottingham, as it is globally, concerns the mobility sector. Through its actions of promoting ever-greener public transport options, low-carbon motor vehicles, and active mobility in the city, Nottingham has become a role model for other cities in the UK. Although the effect of these undertakings is not confirmed by the relevant statistical data, the substantial reduction in carbon emissions in 2017 (compared to 2005) can already hint on the positive impact of this transformation.

To sum up, Nottingham's efforts in becoming the first carbon-neutral city are concentrated on the decarbonisation of the city's energy system, housing stock, and the transport network. The key points of how this is being done is summarised in Figure 4-10.

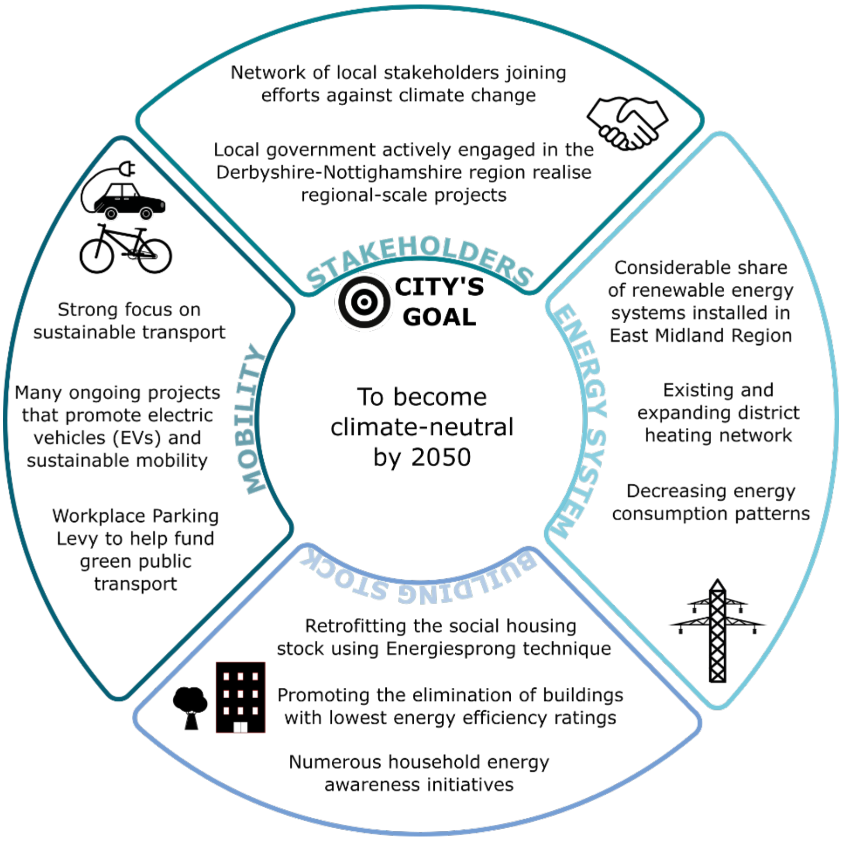


Figure 4-10. Summary of the framework conditions for establishing PEDs with respect to the analysed dimensions – Nottingham

5 The case of Rothneusiedl, Vienna

Case ID: Rothneusiedl, Vienna

Vienna is the federal capital of Austria, with about 1,8 million inhabitants (21% of the country's population) living there. Vienna is also a federal province since 1922, which entitles it to have its own legislative and executive bodies – Provincial Parliament and Government [125]. Simultaneously, Vienna is a municipality with the legal status of a chartered city, which means that the same government operates both for the City and the Province [125]. Thus, the Vienna City Council is also the Provincial Parliament and the City Administration acts as the Provincial Government [125].

Vienna is officially divided into 23 districts (Bezirke) (Figure 5-1(a)) and each district, according to the principles of democratisation and decentralisation, has its political and administrative bodies. They have 4 core responsibilities: receiving and passing on the information concerning their districts, consultation regarding the planned projects in a respective district, cooperation in the decision-making process through delivering their opinion, and autonomy on certain district-oriented tasks including decision independence and budget management [126].

Rothneusiedl, a former separate parish (*Ortsgemeinde*), is now a small neighbourhood in the South of the 10th district Favoriten (blue square in Figure 5-1). It was one of the 13 target areas for the urban development between 2008 and 2014 [129]. The objectives and tasks of this strategy are partly accomplished, as further measures and projects are secured. Therefore, the responsibility for the project was handed over to the urban development bodies [129]. However, up to now only some initial planning activities of the project have started, but no buildings have yet been constructed. Thus, this case study is different from the others in that the neighbourhood under investigation is still in the planning process.

Key priorities: Overall reduction of building energy demand and decarbonisation of transport; creation of a new district with lowest possible demand.

Key achievements:

- New building codes with stricter building energy demand and with recommendations to deploy renewable energy (i.e. nearly zero energy buildings);
- Reduction of private vehicles on the streets and support for EVs and car sharing.

Key challenges:

Integrated planning from scratch of the whole neighbourhood concept considering buidings, mobility and local energy

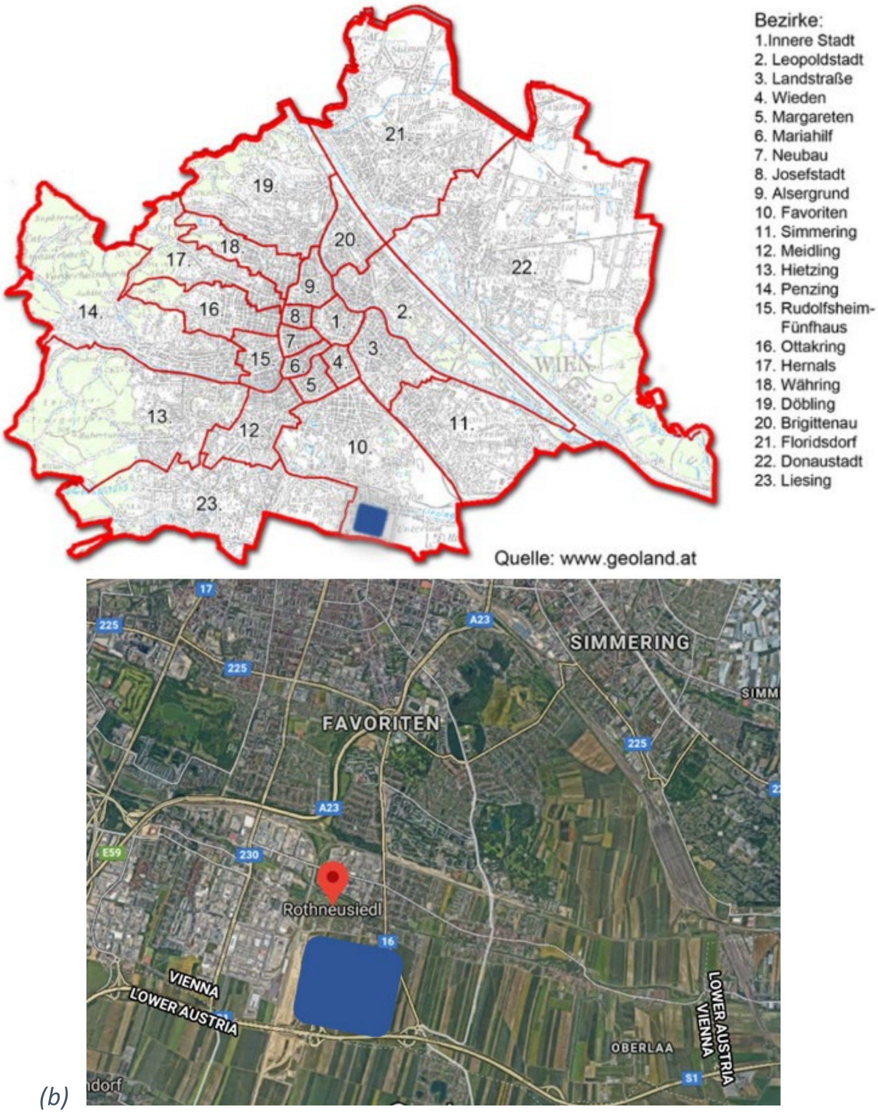


Figure 5-1. (a) Districts in Vienna [127] and (b) the location of Rothneusiedl (blue squares in (a) and (b)) [128]

5.1 The Policy Framework and Policy Stakeholders

Vienna's engagement against climate change started officially with the Climate Protection Program of the City of Vienna – "KliP I" in 1999 [129]. Having exceeded its target with the reduction of 3.1 million tons in greenhouse gas (GHG) emissions by the end of 2008 instead of the planned 2.6 million tons by 2010, the program was extended until 2020 ("KliP II"). KliP II aimed to reduce the total GHG in Vienna by 4.5 million tons and by 21% per capita in 2020 compared to 1990 levels [130]. The per capita decrease of 19% in 2016 was mainly due to the population growth in this period (from 1,492,712 in 1990 to 1,853,140 in 2016), as the total GHG-Emissions slightly increased in 2016 and 2017 from the 1990 level [130] [131].

The **Smart City Wien Framework Strategy**, which is a long-term and comprehensive sustainability strategy with the objective to guarantee sustainability in all spheres of the city's life, was adopted first in June 2014 and updated within the Climate Protection package of Vienna in 2019 [132]. With this strategy, Vienna has pledged its commitment to the 17 SDGs in the 2030 Agenda of the UN and to the international and Austrian agreements and strategies such as the UN Paris Agreement on Climate

Action, the EU climate and energy targets and the Austrian Climate and Energy Strategy "mission2030" [132]. One of the goals is to reduce the per capita GHG-emissions by 50% by 2030 and by 85% by 2050 compared to 2005 level [132]. Choosing 2005 as a reference year here might be related to the fact that the GHG-emissions were far higher (10,257 kt CO_2-equivalent total, 6.3 tCO_2-equivalent per capita) than in 1990 (8,346 kt CO_2-equivalent total, 5.6 tCO_2-equivalent per capita) [131] [133]. The city identified twelve priority themes (including energy supply, buildings and mobility) and used an integrated approach that ensures they complement each other. This methodology should facilitate achieving the goals mentioned above and monitor their progress [132].

The long-term decarbonisation plan of the Smart City Wien 2050 is connected with the operative short-term measures of the relevant departments and institutions through the Vienna **Energy Framework Strategy for 2030** [134]. It is based on existing strategies and serves as a roadmap for measures to be taken, as well as provides the larger framework for numerous existing plans (including the abovementioned Climate Protection Program) [134]. The relationship between the discussed strategies and plans are depicted in Figure B-1. The strategic areas of action within this Framework Strategy are focused around the themes displayed in Figure 5-2.

The strategic areas of action within this Framework Strategy focus on the themes displayed in Figure 5-2. These areas are the basis for separating sub-strategies, for example, spatial energy planning, the energy efficiency plan SEP 2030, or the renewable action plan RAP [134].

Sustainable energy supply	energy-efficient infrastructure, use of waste heat and renewable energy
Spatial energy planning	energy-efficient urban planning
Energy-efficient city	reduced energy consumption in transportation and buildings sectors
Consumption	reduced household energy use via consumer awareness and information
Mobility	prioritisation of public transport, cycling and walking over motorised individual transport
Innovation and digitalisation	ICT for intellgent control of energy systems and city's infrastructure

Figure 5-2. Key strategic areas of action in the Energy Framework Strategy 2030 for Vienna [134]

According to the Energy Framework 2030, energy transformation of the City of Vienna is "fully owned by the city" [134]. The Vienna City Administration Group[14] makes up the steering group of the "Energy Framework Strategy 2030" [134]. It is responsible for the implementation progress of the Framework Strategy and the strategies based on it [134]. Moreover, the implementation of these strategies relies on the cooperation of the Vienna Public Utilities and its subsidiaries[15] [134]. Thus, these infrastructure providers are wholly owned by the City of Vienna. In addition, through the creation of the Climate Advisory Board, the City has strengthened the role and engagement of important stakeholders from science, business, administration, NGOs and other interest groups [135].

Financing of the climate and energy actions is realised through public budgets [136]. The municipal budget is the main source of funding for local activities in Vienna. In 2020, the total budget volume is estimated to be about 16.25 billion euros. In general, the largest spending planned for 2020 are in the areas of social and health security, education and childcare [137]. At the end of 2019, Vienna's City Council has agreed on the Climate Budget (*"Wiener Klimabudget"*), and the plan for 2020 was to have the following sum available:

[14] Namely, the two administrative groups the Administrative Group for the Environment and Vienna Public Utilities and the Administrative Group for Urban Development, Traffic and Transport, Climate Protection, Energy and Public.
[15] Including energy provider Wien Energie, grid infrastructure provider Wiener Netze, and Vienna Public Transport

- 695 million euros for climate-friendly public transport
- 89.5 million euros for climate-friendly building retrofit
- 64 million euros for maintenance and expansion of green areas and forests
- 22 million euros for the climate-friendly redevelopment of public areas [137].

Whether these commitments are realised in 2020 is a big question given the potential impact of the outbreak of COVID-19 at the beginning of 2020 on the budget allocation.

The City's Energy Efficiency Program 2030 (SEP 2030) is one of the sub-strategies of Vienna's Energy Framework Strategy introduced in 2015. It focuses on decreasing the energy consumption per capita by 30% by increasing the energy efficiency in several important areas, especially in mobility and building sectors [138]. This is because 78% of the energy consumption of the city corresponds to these sectors. With this strategy, the city wants to implement energy-saving measures, mainly by improving the infrastructure belonging to the municipal government and its subsidiaries. Twenty-four action packages with more than 80 instruments are presented in the SEP 2030 Report [138].

Some of the highlights of this Strategy are:

- **Spatial Energy Planning** combines energy and urban planning in order to optimise the available resource use. The focus is on connecting local supply and demand, using district and local heating networks, waste heat and renewable energy from the very early stages of planning [138].
- **Climate protection zones** are areas where all new buildings must be supplied with renewable energy (geothermal energy, solar energy or biomass) or district heating. They are defined in the Building Code of Vienna.
- **Measures to switch to renewable heating and cooling of buildings** encompass: refurbishment, shifting from natural gas to heat pump solutions, generating gas from renewable sources, implementing low-temperature heating systems, increasing the share of renewables in district heating (waste heat Large-scale heat pumps, geothermal energy, waste energy in sewers).
- **Optimisation of energy consumption** of the City Administration's buildings that use district heating is realised through a corresponding internal initiative. The buildings are systematically inspected and in case there are significant differences between flow and return temperature in the annual average, an optimisation process is started.
- **Regional energy imports** from rural areas surrounding Vienna are vital, as almost 90% of the energy consumed in Vienna is imported. Since rural regions have more space, it is worth considering large-scale renewable production there.
- **Transition to electromobility** requires buildings to provide the infrastructure necessary to connect electromobility with renewables and the power grid.
- **Promotion of innovation** with the Green Energy Fund through PV subsidy, electricity storage and energy efficiency programmes.
- **Informational instruments** include education campuses and raising awareness for energy issues and climate protection among young people through energy literacy certificates.
- The initiative "Energy consulting for households at risk of poverty" helps lower energy costs and **prevent energy poverty**.

The abovementioned strategies and actions make up the current climate and energy policy pathway of Vienna (Figure 5-3).

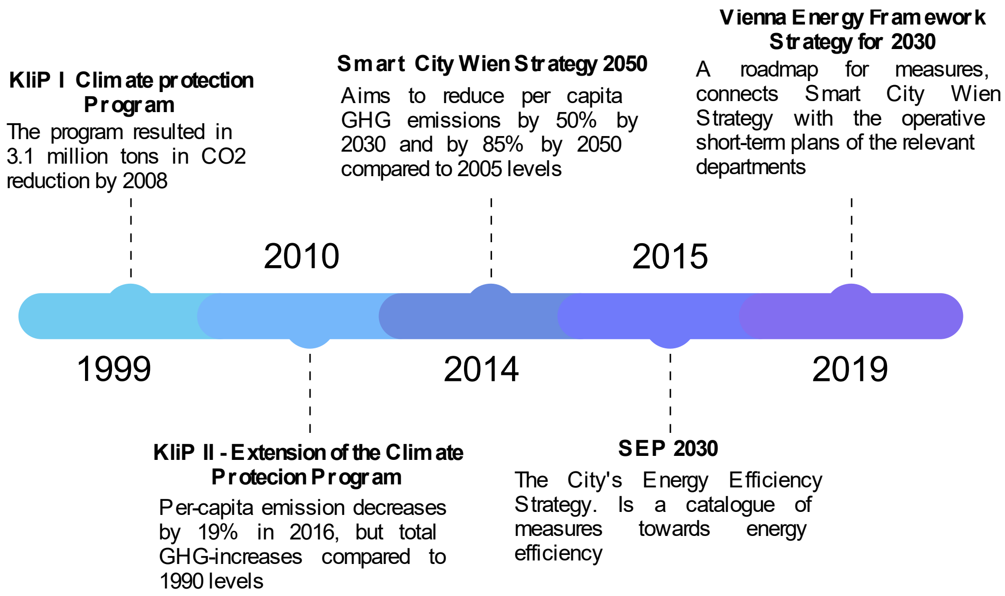


Figure 5-3. The climate and policy pathway of Vienna

5.2 Building Stock Condition in Vienna

Rothneusiedl is a small neighbourhood, which was a separate parish (*Gemeinde*) before becoming part of Vienna. It is situated in the south of the 10th district, close to the city borders. The existing neighbourhood is a small area to the north of the red zone in Figure 5-4. An area of roughly 120 ha that is currently mostly used for agricultural purposes is available to the south of the existing neighbourhood.

A new urban development project is intended in that territory (s. red area in Figure 5-4). It will comprise residential housing, offices and commercial areas, educational facilities, production and operation areas (for logistics, energy, wholesale business, repair works, etc.), and others.

Due to the lack of detailed information about the planned future neighbourhood, it is not possible to indicate in detail the specifics about buildings to be constructed in Rothneusiedl. Therefore, it is relevant to discuss the regulations under which the planning and construction of the new neighbourhood will need to take place. These are – among others – the building codes, the land-use plan and the zoning process, which are explained in some more detail below.

The site is currently under a construction block according to the §8 (1) of the Building Code for Vienna (*Bauordnung für Wien*), which means that nothing can be constructed in the territories not covered by the Land-use plan (*Bebauungsplan*) until these plans are fixed [139] [140]. However, at the moment, the area is not yet under the zoning process (*Flächenwidmungsverfahren*) [141]. The reason for the prolongation of the project planning phase could be related to the lack of public acceptance for this project [142].

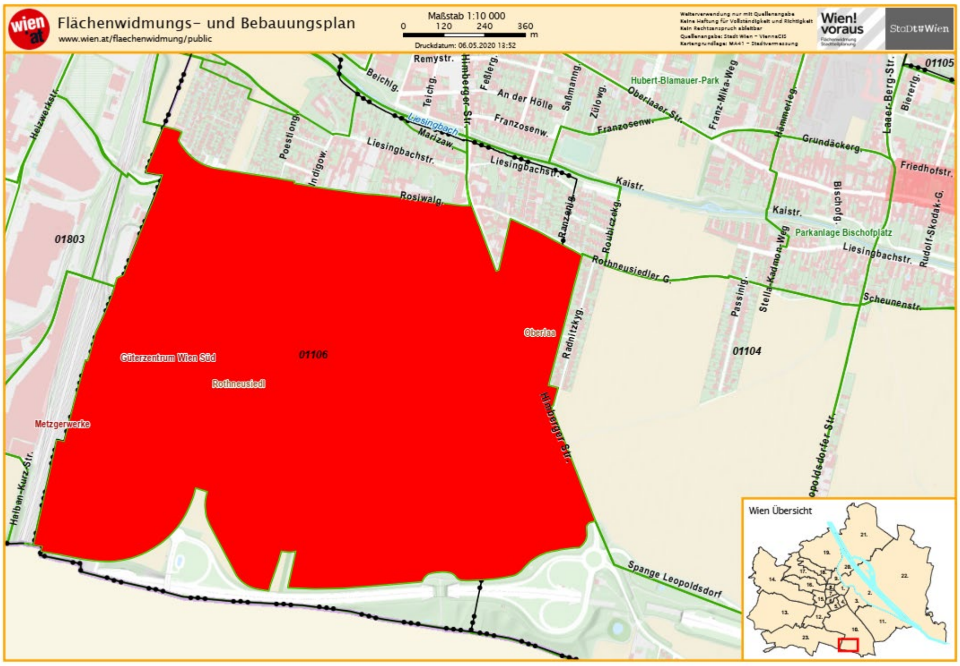


Figure 5-4. Cadastral map of Rothneusiedl (black lines – the borders of the geographical division ("Katastralgemeinde"), red area – territory for the new urban development in Rothneusiedl) [139]

The requirements for this new living area are known, and they are in line with the PED goals [143]:

- high living and staying quality
- use of green area concept of Vienna (Grünraumkozept Wiens)
- climate-neutral
- renewable energy supply
- participation of the general public (i.e. discussion platforms).

From these, it could be deduced that buildings are to be constructed according to the highest standards, with a very low energy demand and with local energy production. Therefore, it's worth looking into the **existing building standards** that are in use in Vienna. They reflect the minimum standards which new buildings must meet.

The Austrian Institute of Construction Engineering (OIB) is the institution responsible for issuing the guidelines to which all buildings must adhere. The OIB Guideline 6 contains a series of mandatory requirements for heating and energy savings for new buildings and buildings undergoing major renovations. With time, the regulations have become stricter mandating higher energy savings for new buildings. Figure 5-5 shows the maximum space heating demand allowed in new buildings, pointing out how stringent it is becoming with every new guideline. The maximum values are calculated as a function of the Area/Volume ratio. The state of Vienna has already accepted the current OIB guidelines to enter into force from February 2020 [144].

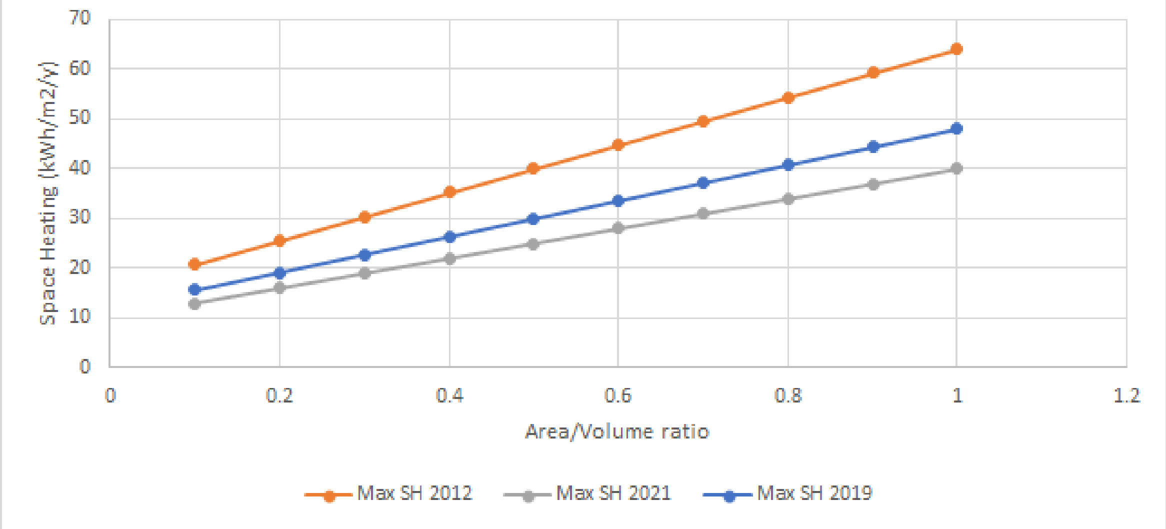


Figure 5-5. Yearly maximum allowed final energy need for space heating according to OIB guidelines [145]

The guidelines are very detailed and specify the maximum allowed heat dispersions per each element of the building (external façade, windows, floor to soil, ceiling, etc.). All buildings comprising more than two flats must utilise a central heating system for space heating and domestic hot water, with few specific exclusions. It is also strongly suggested to install PV panels to cover part of the electricity demand, especially for heating and auxiliary services. PV system should be installed directly on the building or in the close vicinity [145]. Moreover, all heating systems must be highly efficient or from renewable energy sources. This definition includes a decentralised energy supply from renewable sources, district heating and cooling, and heat pumps. To not leave any space to interpretation, the guidelines provide a list of renewable sources [145]. The temperature of the heating system is also set. In case heat pumps are used, they should supply heat at a low temperature of 40 °C, while this is 55 °C in any other case. These constraints are also compliant with future 4th generation district heating low-temperature level [145].

Whether these standards are a sufficient condition to achieve the status of Positive Energy District will be further analysed in the next steps of the Smart-BEEjS project. High energy efficiency is necessary to achieve a positive energy balance, but it is not sufficient. As briefly discussed in the introductory chapters, many factors will make a Positive Energy District a reality.

Assessment systems or certificates for sustainable buildings are becoming more widespread, and new facilities are being assessed and awarded certificates in Vienna [146]. At the moment, there are six assessment systems relevant to the Austrian real estate market: GreenBuilding Label from the EU, klima:aktiv, TQB/ÖGNB, etc. [147]. Among these, TQB/ÖGNB and ÖGNI, are the strictest ones. They consider economic and socio-cultural criteria, such as alternative use in the future, life cycle costs, architecture and art, that are often omitted by the others. These could be a good starting point for establishing the assessment criteria for PEDs in future.

5.3 Energy System and relevant Stakeholders in Vienna

In Vienna and also most of the rest of Austria, the independent TSO is Austrian Power Grid (APG) operating on a mix of 380 kV, 220 kV and 110 kV transmission lines. Locally, Wien Energie manages the actual production of energy through CHPs, waste-to-heat plants and gas peak load boilers [148], whereas Wiener Netze GmbH as the DSO is responsible for the distribution grid and the connection points to the final customers. In addition to the electricity grid, Wiener Netze is also in charge of the gas grid, the district heating network and a telecommunication network [149]. Both companies together own and operate the largest district heating network in Austria[16]. They are also part of Wiener Stadtwerke, which are also involved in energy generation and mobility services [150]. The heat also serves to produce cooling for buildings, although Wien Energie does not specify how many customers they supply.

Locally generated energy carriers in Vienna constitute 13.5% of the city's energy consumption (Figure 5-6). The remaining part is covered by importing energy from surrounding areas, with a high share of fossil sources such as gas and oil. A detailed energy flow overview by the city of Vienna can be found in Figure B-2 in the Appendix. [138].

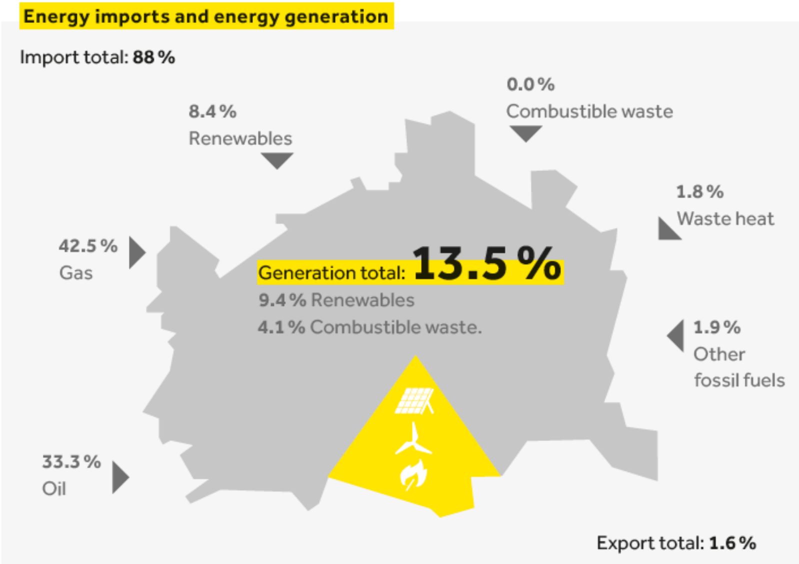


Figure 5-6. Vienna Energy Balance [138]

The share of renewable energy in the gross final energy consumption in Vienna has been increasing over time (Figure 5-7). In 2014 the percentage of renewable energy was comparably high. A combination of a slight overall final energy reduction combined with an increased renewable energy generation explains this [151]. It has to be taken into account that data in Figure 5-7 also include imported renewable energy.

[16] As of today, it counts 1200 km of pipes, serves 400,000 apartments and almost 7000 large scale customers in Vienna [148] [245].

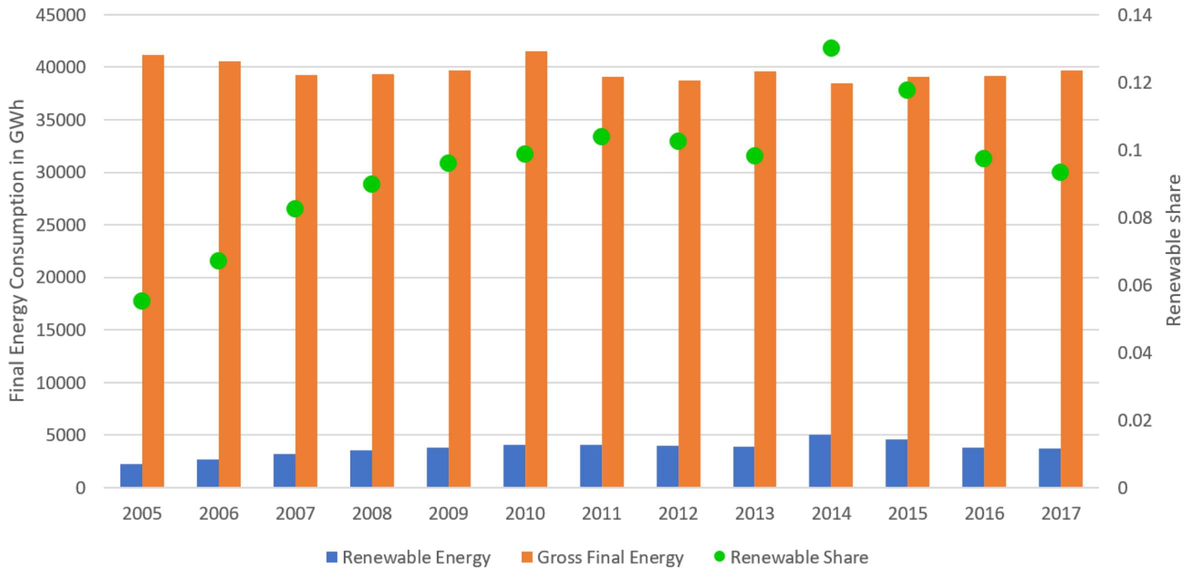


Figure 5-7. Share of renewable energy of gross final energy consumption in Vienna over time [151]

Renewable energy generated in Vienna comes mainly from hydropower (almost 80%), while another 12% comes from wood residuals (Figure 5-8). As for PV power, Vienna had 30.5 MWp of installed capacity in 2017. In absolute terms, the district with the highest installed capacity was Liesing with 7.3 MWp, followed by Donaustadt and Floridsdorf with 5.8 MWp and 4.1 MWp, respectively. Favoriten, where the discussed brownfield is, shows the 5th highest installed PV capacity (1.7 MWp), while per capita it only has the 11th highest installed capacity [138].

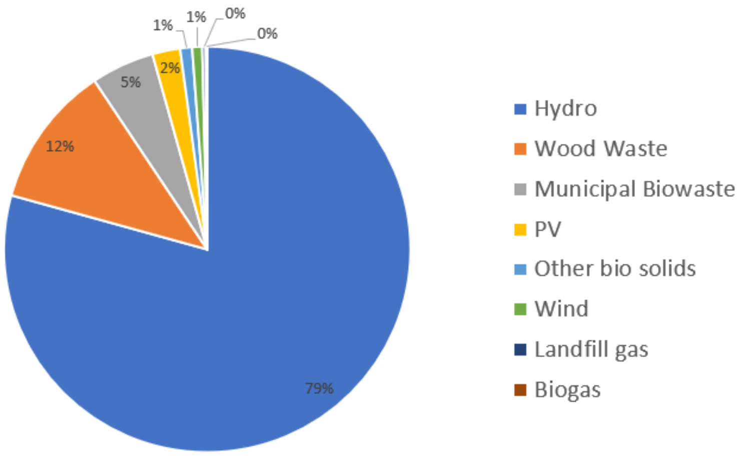


Figure 5-8. Electricity generated from renewable sources within Vienna [152]

The part of Rothneusiedl that is to be developed does not have small scale distributed energy generation nor large scale power generation yet. However, in close proximity, there are multiple subsidised PV installations, a wind farm to the east and a natural gas powered large scale district heating generation plant to the west (Fernheizwerk Süd, 358 MW_{th}) [153]. Additionally, according to google maps, an electricity substation is right to the east of the site. The proximity to the substation is propitious, for example, to community wind farms in the south of the area. The website of the city of Vienna provides this information, along with a map of energy generators and energy generation potential from wind, heat pumps, solar and waste heat [153]. The generation presented on the map includes subsidised solar PV installations with and without storage, subsidised solar thermal installations as well as hydropower plants, wind farms, biomass generation and conventional plants.

As Figure 5-9 shows, the overall energy consumption in Vienna grew from 1993 to 2003 and later decreased slightly and remained mostly stable until today. In 2017, approximately 50% of this consumption was for heating purposes, 37% was for mobility, and only 13% was used for electric appliances. While heat usage only grew by 5% since 1993, electricity usage grew by 22% and mobility related consumption by 30% [154]. In Figure 5-10, the per capita consumption, according to the sector, is shown. First of all, it can be observed that the consumption per capita decreases, while the total consumption stagnates. This could be an indication of more efficient energy usage overall. Secondly, the majority of the consumption by sector is associated with transportation (37%), followed by the residential sector (31%), services (23%) and industry & agriculture (9%). While transport and service-related per-capita consumption grew between 1993 and 2017, the per-capita consumption by industry & agriculture and residential sectors decreased [155].

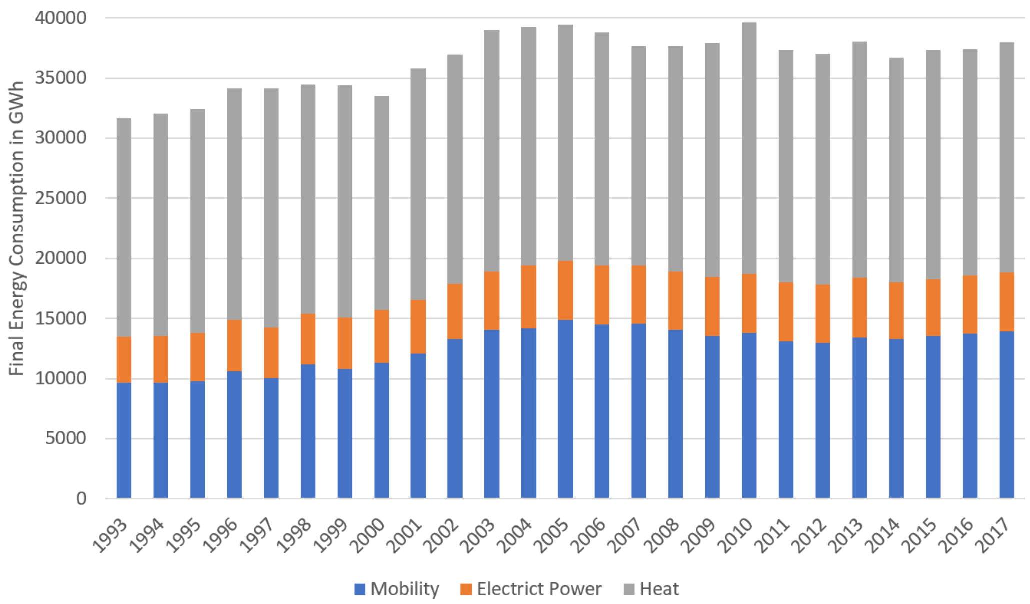


Figure 5-9. Final Energy Consumption in Vienna by application [154]

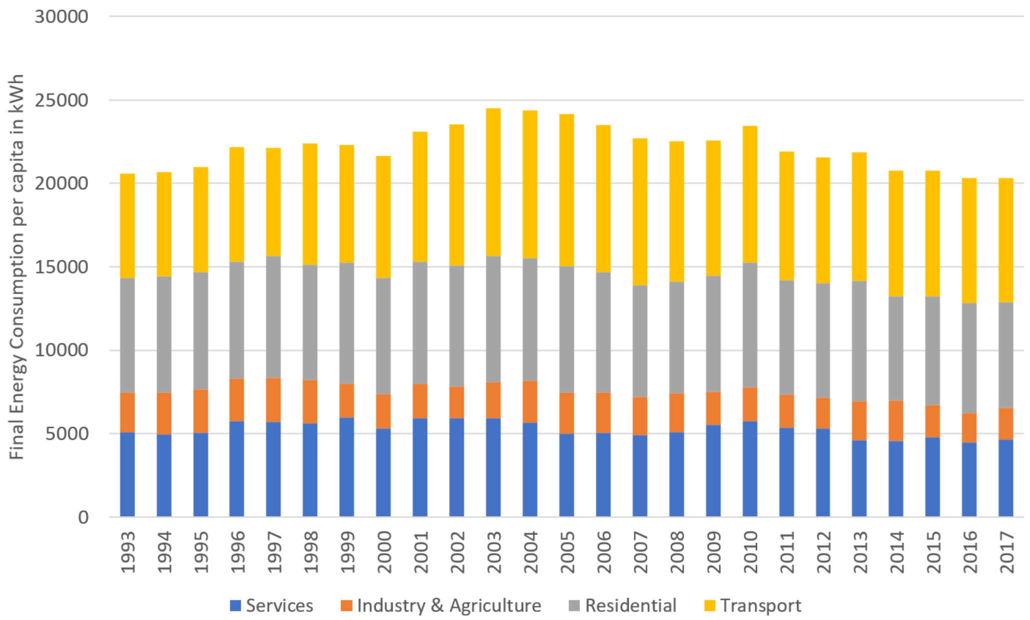


Figure 5-10. Final Energy Consumption in Vienna per capita by sector [155]

Figure 5-11 illustrates the development of the CO_2 equivalent emissions of Vienna from 1993 to 2015. The emissions peaked around 2005 and decreased by more than two megatons of CO_2 equivalent until 2015, while the year 2014 marked the lowest. Dwelling associated emissions appear to steadily decrease over time, while energy-related emissions seem to fluctuate, but also showed a substantial decrease in the most recent years. Also, transportation-related greenhouse gas emissions decreased since peaking in 2005. However, in 2015 they represented the largest share by far with 39%, followed by energy supply and buildings with 24% and 18%, respectively [156].

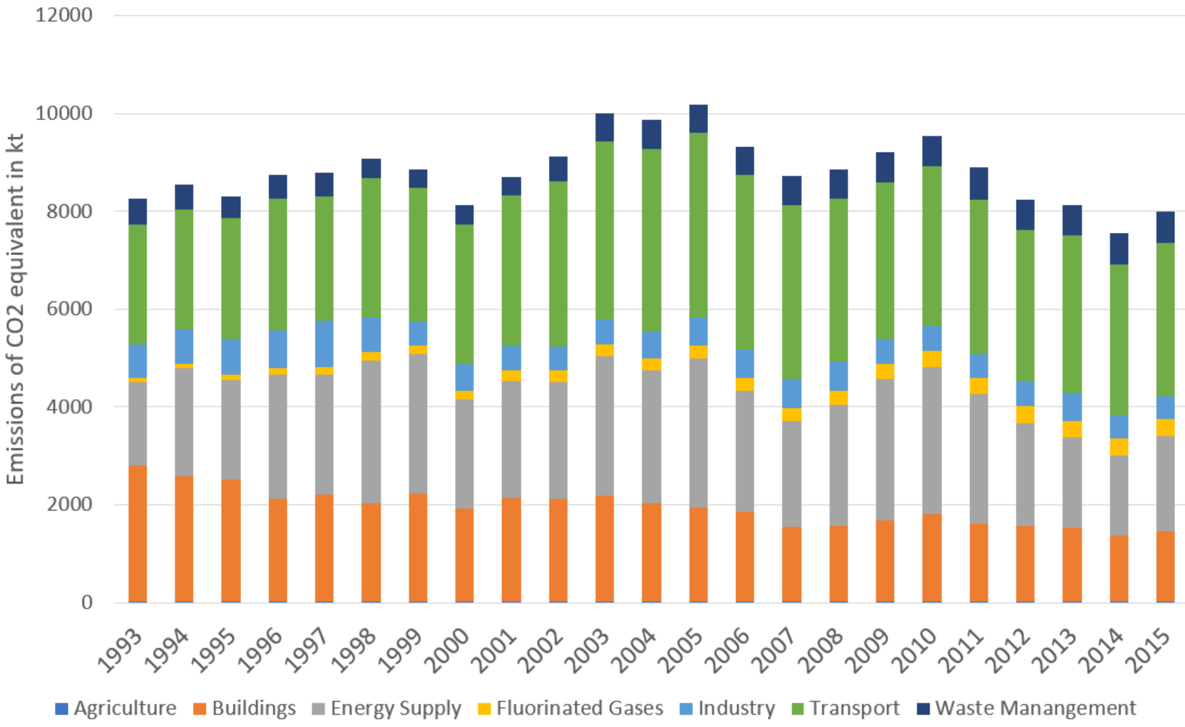


Figure 5-11. Vienna's CO_2 emissions by sector [156]

The energy consumption of the district is yet unknown. It will depend on the shares that each sector, such as residential or industrial, takes, the types of buildings built and their energy performance (see also chapter 5.2.

5.4 Mobility and the Transition to Sustainable Mobility in Vienna

According to the goals set in the city’s Urban planning strategy STEP 2025, at least 80% of all trips taken in Vienna in 2025 should be by public transport, on foot or by bike, whereas the long-term strategy Smart City Wien aims at 85% by 2030 and more than 85% by 2050 [132] [157]. In 2019, this share was 75%; that of walking was equal to 30%; that of cycling, 7% [158]. Thus, the share of trips made in Vienna on foot and by bike exceeds that of trips by car. Over the years, the number of trips by active and public modes of transports has increased, while those of car trips have decreased (Figure 5-12).

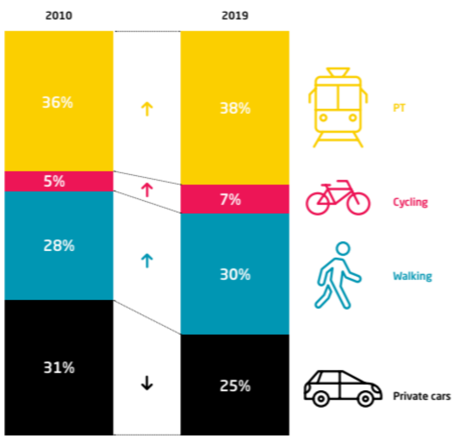


Figure 5-12. Development of modal split in Vienna from 2010 to 2019 [158].

Public transport in the city is provided by the Wiener Linien, which is a 100% subsidiary of the Wiener Stadtwerke – Vienna's public utilities [159]. Wiener Linien thus closely cooperates with the city from the early stages of public transport planning. Environmental friendliness plays a vital role for the company: it invests into alternative fuel public transport (hydrogen, electric buses), recycles some materials, integrates PV systems to power the station lights, and promotes the use of public transport as a less energy and emission-intensive means of transport compared to private cars [160].

Wien Energie, another 100% subsidiary of the Wiener Stadtwerke, has built a dense network of EV charging stations (every 400 m a charging station) [161]. This removes the infrastructural barriers for the uptake of e-vehicles. Therefore, there are also many e-carsharing providers in the city: ÖBB (Rail&Drive), car2go Österreich GmbH (SHARE NOW), greenmove GmbH (Stadtauto), Caroo Mobility GmbH (ELOOP), etc. There is only one bike-sharing system – Citybike Vienna – operated by a marketing agency Gewista [162]. Mobilitätsservices GmbH (MO.Point) offers a wide variety of e-vehicles. All of the companies work in close cooperation with the City authorities.

The transport providers within the regional transport network are the Transport Associaton East Region (VOR) and the Austrian Railways (ÖBB). VOR is responsible for the transboundary planning, financing and coordination of the whole public transport in the provinces of Lower Austria, Burgenland and Vienna. ÖBB is the owner of the railway infrastructure and provides a wide range of mobility services (passenger transit, cargo and goods transport, etc.). Sustainability is one of the main priorities of the company: ÖBB powers the trains from 100% renewable energy and invests in innovative projects that save energy and resources [163].

5.4.1 Active modes

Walking is a popular mode of transport, as Vienna is – at least partly – a city of short distances, where housing, work and open spaces are well-mixed. According to the surveys done by Mobilitätsagentur Wien GmbH in 2019, the majority of Viennese people like to walk, feel safe walking and are content with sidewalk lengths [158]. However, the respondents also suggested several improvements, such as separating footpaths from cyclists and electric scooters, placing more benches, increasing the green traffic light and shortening the waiting times at traffic lights.

Since 1974, 100 pedestrian zones were created in the city. As observed from Figure 5-13, the lengths of other measures to make streets more pedestrian-friendly have been steadily growing [158].

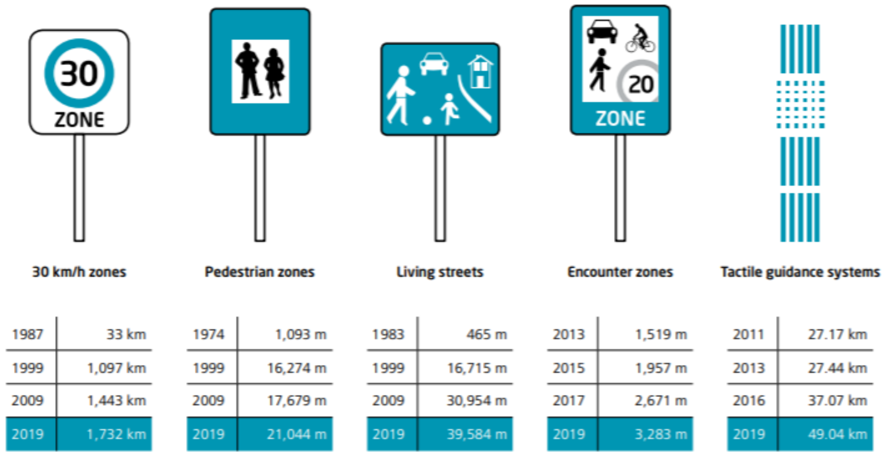


Figure 5-13. Pedestrian-friendly streets [158].

As for cycling, the share of cyclists has increased from 3% in 1993 to 7% in 2018 [164]. Moreover, the surveys show that cyclists have a higher opinion of the cycling infrastructure than before [158]. Bike parking and cycleway network has been expanding steadily, and the average number of cyclists has increased remarkably since 2010 [158]. As of 2019, 49,101 bike parkings and 1,431 km of bike tracks extend city-wide [158].

5.4.2 Public transport

Public transport is widely used in Vienna. The five metro lines have been used by 463.1 million people, the 28 tram lines by 305.8 million people and the 129 bus lines by 197.3 million people in 2018 [164]. Figure 5-14 depicts how public transport has "pushed out" a part of the private motor traffic use over three decades.

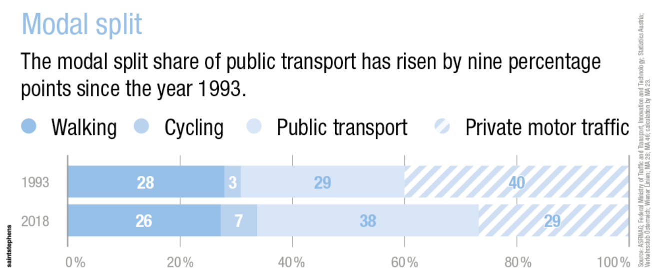


Figure 5-14. Modal splits in Vienna in 1993 and 2018 [164].

The new neighbourhood Rothneusiedl lies close to the metro (U-Bahn) line U1, the longest line among the five. When building the track to Oberlaa, it was decided to prepare the station Alaudagasse for intersecting the two lines – one to Oberlaa and one to Rothneusiedl [165]. For now, there is only one bus line that passes through the old part of Rothneusiedl (Figure 5-15).

Figure 5-15. Public transport connection to Rothneusiedl [165].

5.4.3 Motorised private transport

According to the 2014 study by the Institute of Transportation, Research Center of Transport Planning and Traffic Engineering at the Vienna University of Technology, an average of 900 g CO_2 is produced per trip by a car, compared to 161 g via public transport [157].

While the modal split of cars in the city is relatively low (around 30%) and has been decreasing, the importance of private motorised vehicles is still high among those who commute to and from Vienna. In the traffic between Vienna and the surrounding territories, the modal share of cars was estimated to be 79 per cent [157]. The situation is especially problematic along the southern border, which is crossed by 220,000 vehicles in both directions every day [146]. Moreover, the number of cars registered in Vienna grew to 709,288 in 2018, which is an 8% increase over 2004. Although electric vehicles are on the rise in Vienna (2,252 in 2018) they still only resemble a small fraction of the total (709,288 private motor vehicles) [164].

The share of individual vehicles in the modal split is planned to be decreased to 20% by 2025, while the rest of the transportations will be met through bikes, walking and public transport, according to the conceptual plan included in the urban development plan STEP 2025 [166] [167]. The following measures are planned to achieve this [166]:

- Rollout of charging infrastructure for EVs (Electric Vehicles)
- Expansion of subsidies for fleet electrification
- Integrated solutions for private and business customers
- Use of e-taxis, electric and hybrid buses
- Support for research and innovation, mobility labs
- Awareness-raising.

In 2015 the number of carsharing users in Vienna hit the mark of 100,000 [168]. Some companies, such as Share now or ELOOP, provide e-cars for rent on an hourly or minutely basis.

5.5 Concluding Remarks

An ever-growing metropolitan city of Vienna has set ambitious goals to reduce its per capita emissions by 85% until 2050 compared to 2005 levels. It is taking decisive steps towards this target, by focusing on sustainable urban and energy planning, integrating digital technologies, decreasing building energy demand through stricter building codes, and promoting sustainable transport modes.

Despite most of the electricity mix being from renewable hydropower, the government is making efforts to further decarbonise the energy system by focusing on waste heat, renewable heating and power-to-heat. However, the newest building codes promote the integration of small-scale distributed systems. This is especially relevant for newly built or renovated buildings. Tremendous effort is shown for making the building stock more energy efficient, which is the consequence of numerous retrofit projects and strategic energy planning in Vienna. For newly built districts, the standards are expected to be very strict, which will ensure low energy demand by buildings.

Despite the numerous efforts to discourage private car ownership, promote sustainable modes, and reduce the overall need for travelling by effective city planning, the emissions by the transport sector still constitute a significant share of total emissions. The new EV subsidy, ever-growing network of charging stations and inclusion of chargers in the district planning might bring some changes in this regard.

The goal of the municipality to become climate-friendly is supported by the major stakeholders in the city that provide heat, electricity, transport services, etc. This is mostly because these companies are municipality-owned “Stadtwerke,” which closely cooperate with the government and the public. This framework seems to be efficient in bringing changes. However, a more detailed study could be done in the future to see the full picture.

In relation to the dimensions studied within this work, the framework conditions for developing PEDs in Vienna (and Rothneusiedl) can be summarized with the following diagram (Figure 5-16).

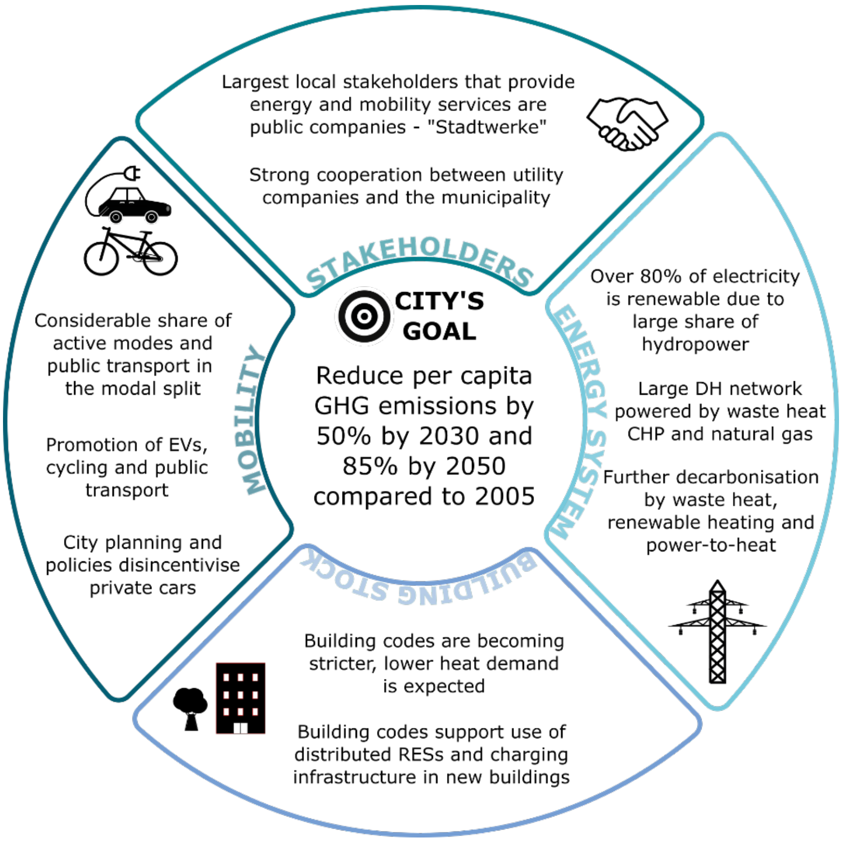


Figure 5-16. Summary of the framework conditions for establishing PEDs with respect to the analysed dimensions – Vienna

6 The Case of Torres Vedras

Case ID: Torres Vedras

Torres Vedras is the largest municipality in the district of Lisbon (Figure 6-1), located approximately 50 km north of the capital and in the western part of the Centro region and Oeste subregion. The municipality covers an area of 407.20 km^2 and has 20 km of coastal area with more than 22 "praias" (beaches) [169]. It is well renowned for its agricultural variety and its vineyards, which makes the municipality the largest producer of wine in the country. Retail trade, metallurgy and tourism are other important sectors of the local economy.

The whole municipality is home to 78,530 people and is divided into several smaller urban areas, of which most have less than 2,000 inhabitants [170] [171]. Torres Vedras town represents 22% of the population residing in the municipality, amounting to almost 18,000 people. Administratively, the municipality is divided into 13 civil parishes (Freguesias) [172].

Torres Vedras is interested in the city-wide concept of PED.

Key priorities: Transformation of the transport system and social inclusion of citizens.

Key achievements:

- European Green Leaf award for the sustainability initiatives;
- Introduction of bike-sharing, installation of EV charging stations, bus stops in key spots, purchase of electric buses, construction of bike lanes and traffic control infrastructure, citizen participation in planning.

Key challenges: High share of private transportation due to a large share of commuters, lack of advantages in using intraregional public transport, and cultural/habitual reasons.

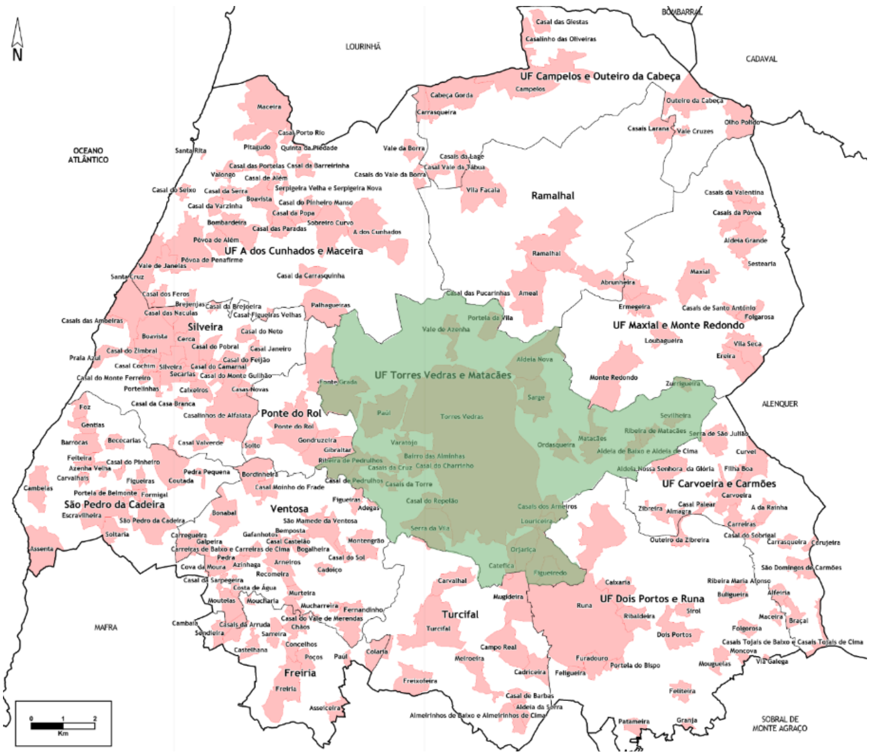


Figure 6-1. Municipality of Torres Vedras (the green area marks the Torres Vedras parish) [173]

6.1 Policy Framework

Portugal has no endowment of fossil energy in its territory; therefore, local and renewable production has both strategic and environmental importance. The government has announced its aim to transition to a complete carbon-neutral economy by 2050, producing 80% renewable electricity by 2030. The third National Energy Efficiency Action Plan (NEEAP 2017-2020) has set even more ambitious targets despite the economic difficulties. With this plan, Portugal aims at reducing the primary energy in all state-owned facilities by 25-30% by 2020 [174]. Torres Vedras municipality[17] endorses and implements the national plans for decarbonisation of the economy such as the National Strategy for Sustainable Development, the National Strategy for Biodiversity and Nature Conservation and the National Strategy for Climate Change Adaptation [175]. These national directives represent the starting point for the local action implemented by the municipality[18] through the Estratégias Municipais de Adaptação às Alterações Climáticas (EMAAC – Municipal Climate Change Adaptation Strategies). This is also the basis for the commitment to the Covenant of Mayors, of which the municipality of Torres Vedras is part since 2010. All these commitments sum up in the decision to reduce carbon emission by 29% and electricity consumption by 21%, compared to 2009 levels, before 2020 [176] [177].

Torres Vedras is also a signatory of the Aalborg Charter initiative to set the notions for sustainable economic and social development in cities since 1994 [178] [179]. In 2007, the municipality initialised the implementation of the Aalborg Charter, starting the first phase of the Local Agenda 21, a plan to reach a sustainable, just, inclusive and sustainable community. One year later, the Local Agenda 21 started its second phase, which introduces the intervention strategy and the action plan through a collaborative and participatory process [180]. Finally, in 2015 the Torres Vedras Agenda 2030 made its appearance as a successor of the Local Agenda 21. This new plan implements the UN's Sustainable Development Goals and represents a solid continuity to all previous efforts [180]. These pledges demonstrate a long-time commitment in the principles towards the improvement of the environment, enlarging renewable energy generation and citizen participation.

Over the years the municipality invested in developing active mobility, renewing and renovating public transport, enlarging the share of renewable energy production into the energy mix of the municipality and extending the network of public spaces for improving the quality of life and increasing citizens' connection with nature[19] [181]. To further strengthen the continuous citizen participation in the green transition, the Municipal Chamber, in cooperation with NASA, built the new Environmental Education Centre[20], where children learn about recycling, mobility, climate change, sustainability and nature conservation, creating environmental awareness [182]. For these and other environmental achieveents, Torres Vedras was awarded the European Green Leaf in 2015 (Figure 6-2) [183].

[17] The Camara Municipal of Torres Vedras (Municipal Chamber) is the main body responsible for taking important initiatives in the city. The municipal chamber is composed by its president (the mayor) and the aldermen. The number of aldermen for each district represents the population of the area (8 for Torres Vedras town) [244].
[18] The municipality is divided in 13 departments. The ones related to policies and environment are: Strategic Department (Departamento de Estratégia – DE); Financial Division (Divisão Financeira – DF); Public Procurement and Properties (Divisão de Contratação Pública e Património – DCPP); Administrative Division (Divisão Administrativa - DA); Cultural Heritage and Tourism Division (Divi são de Cultura, Património Cultural e Turismo - DCPCT); Division for Social Development (Divisão de Desenvolvimento Social – DDS); Division for Urban Management (Divisão de Gestão Urbanística – DGU); Environmental and Sustainability Division (Divisão de Ambiente e Sustentabilidade – DAS); Infrastructure and Municipal Endevours (Divisão de Infraestruturas e Obras Municipais – DIOM); Division for Managament of Urban Areas (Divisão de Gestão de Áreas Urbanas – DGAU); Transports and Transit Division (Divisão de Transportes e Trânsito – DTT).
[19] Actions financed mainly by the Operational Program for Oeste Region (Programa Operacional Regional do Centro), Portugal2020 and the European Union's Regional Development Fund.
[20] An exemplary building on energy efficiency

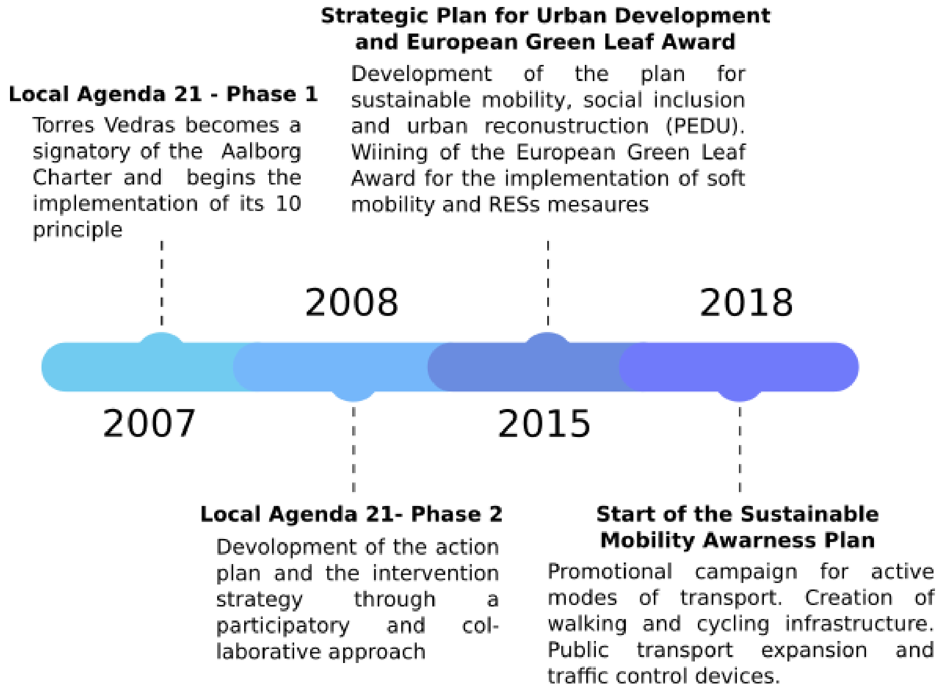


Figure 6-2. The climate and energy policy pathway of Torres Vedras

Recently much of the municipality's efforts have been directed towards active mobility and utilisation of the mobility system, in parallel with an effort of modernising the built environment and reducing inequality. As part of the program Portugal 2020 (the national initiative to meet European 2020's goals), the municipality of Torres Vedras has developed a comprehensive program called Strategic Plan for Urban Development (Plano Estratégico de Desenvolvimento Urbano – PEDU) [181]. PEDU includes three instruments, with a budget of 12.5 million euros, until 2021:

- Action plan for **sustainable urban mobility** (Plano de Ação de Mobilidade Urbana Sustentável - PAMUS) – implementing soft mobility measures such as bike-sharing and EV car sharing. It created pedestrian only areas, constructed bike lanes and strengthened public transportation [181] [184] [185].
- Action plan for **urban reconstruction** (Plano de Ação de Regeneração Urbana – PARU) – regeneration and requalification of public spaces, renovation of buildings to decrease energy consumption [186] [187].
- Action plan for **integrating disadvantaged communities** (Plano de Ação Integrada para as Comunidades Desfavorecidas – PAICD) [188] [189] [190] – improving social inclusion of vulnerable areas.

Following the European Union's strategic framework for the coming decades, Portugal has developed a new plan for the following decade (2021-2030) to decrease greenhouse gases emissions further and increase the share of renewable energies. The vision includes the legal recognition of Energy Communities[21] from the start of 2020, which are of vital importance to foster self-consumption and self-production from renewable energies without putting too much stress on the national electric grid.

[21] In Portugal renewable energy generation is divided into Small Production Units (called UPPs) and Self-Consumption Units (UPAC), mainly households. The amount of money received as Feed-in-Tariff (FiT) changes according to the source utilised but also the year of installation. For example, existing photovoltaics have a FiT of 257 €/MWh, while new installations only receive 95 €/MWh. It has to be noticed that the latter is subject to changes as it is linked to the reference tariff, a value determined through government's ordinances [249].

The participation of the citizens is encouraged through the Orçamento Participativo de Torres Vedras (Torres Vedras Participatory Budget). The local population has the opportunity to propose their own ideas and projects to the city council. The range of topics that can be proposed varies significantly, ranging from education and youth to transportation, housing and public spaces. The city council redirects a total of 300,000€ to finance the winning ideas, which are chosen by the same citizens through an online portal [191] [192].

6.2 Building stock condition

Currently, there are more than 33,000 buildings (estimated values for 2019) dedicated to residential use in various forms (apartments, villa, multi-storey, etc.) for a total of almost 46,000 dwellings [193] [194]. As a comparison, in 2011, there were only 169 mainly non-residential buildings in the area of Torres Vedras [195]. There has been a slow increase in the total amount of dwellings and residential buildings over the years (Figure 6-3).

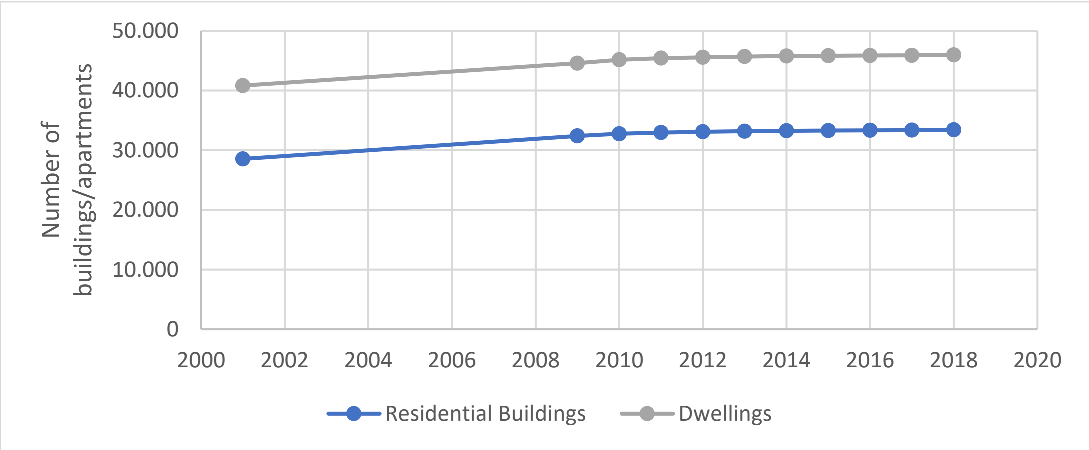


Figure 6-3. Total number of residential buildings and dwellings in Torres Vedras [193] [194]

There is no sufficient information available on the current state of the building stock in Torres Vedras[22]. Since 2009, there has been a steep decrease of heat demand in Portuguese apartments (Figure 6-4). This might be due to the economic crisis rather than a sudden improvement in the building stock. It is difficult to surmise at this stage what causes the low heat demand shown in 2017 (1.6 koe = 18.6 kWh) without further information about the conditions of the buildings and the relation to the 2009 economic crisis. Noteworthy is that even during pre-crisis times, heat demand was incredibly low (in 2003 it was 2.2 koe/m^2 corresponding to 25.6 kWh/m^2). As a comparison, a residential unit of 100 m^2 in Palermo (Sicily, Southern Italy) uses around 40 kWh/m^2 for heating [196]. This might suggest a habit of not heating an apartment adequately, rather than having a smaller demand because of the local climate. As for space heating, also space cooling suffers from a lack of information. In 2015, Werner estimated that in Portugal, there is a specific cooling demand in the residential sector of 36 kWh/m^2 [197]. For a comparison with other south European countries, Greece, Italy and Spain have a demand respectively of 66, 51 and 59 kWh/m^2. Although relatively low when compared to countries with similar weather conditions, there is a consensus that future space cooling demand will increase due to climate change [198], which might pose more challenges in warmer countries to supply renewably generated electricity.

[22] The research team at the moment of the publication of this report has not identified data regarding the the age of the buildings, their current state of renovation and heat/cooling demand.

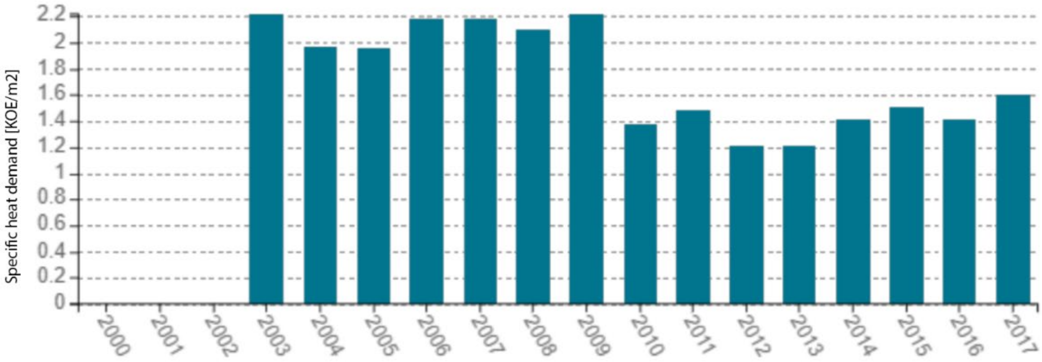


Figure 6-4. Specific heat demand for residential buildings in Kilo of Oil Equivalent per m² [199]

6.3 Energy System and relevant Stakeholders

The Portuguese electricity and gas markets are regulated by the Entidade Reguladora dos Serviços Energéticos (ERSE) [200]. The only state-licensed TSO in Portugal is "Redes Energéticas Nacionais" (REN), who, along with the electricity distribution, also manages that of natural gas [201]. The main distribution system operator in Portugal for high, medium and low voltage grids is EDP Distribuçaõ. While the high and medium voltage distribution grids are operated by EDP Distribuçaõ completely, the low voltage gird is controlled under concession agreements. In total, EDP Distribuçaõ manages around 99% of Portugal's mainland distribution grid. The small exceptions are electricity cooperatives and prosumers [202] [203]. Since 2013, customers in Portugal can choose among a variety of suppliers, such as, Endesa, Galp Power, Iberdrola Generacion; though EDP still has a dominant position [204].

Portugal evolved from a fossil-based electricity generation with a share of hydro to a system that generates approximately 51% of its yearly supply by renewables in 2019 (Figure 6-5). [205]. In certain months, such as December, renewables deliver up to 77% of overall generation [205]. This occurs especially due to the growth of wind power generators (23.8% in May, 2020). Contributing almost 3% to the generation mix (May 2020), solar PV is also on the rise [205]. Another interesting fact visible in Figure 6-5 is the excess production between 2016 and 2018, which was exported to the economic benefit of the country [206].

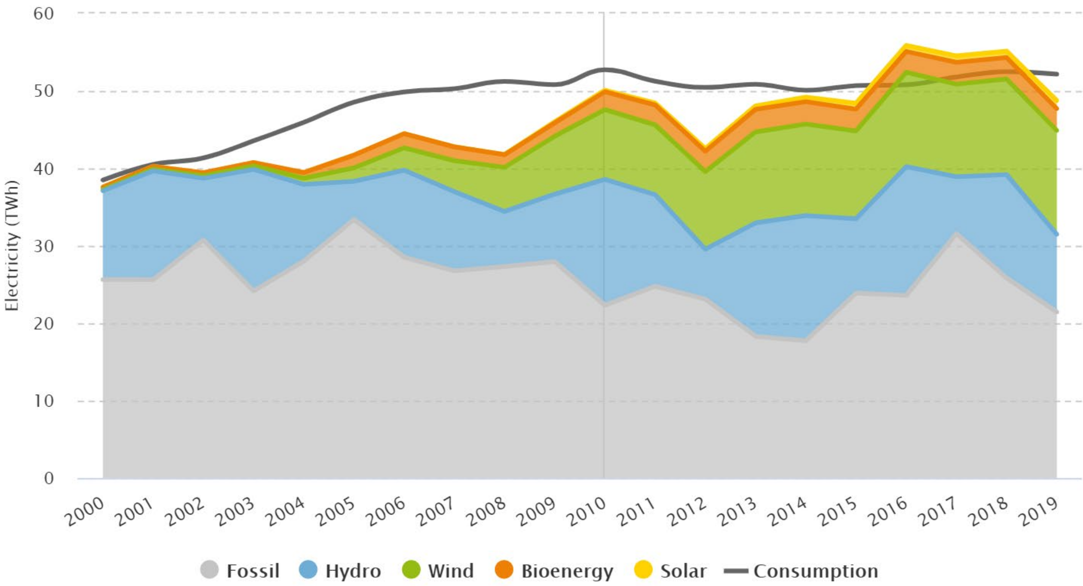


Figure 6-5. Mainland Portugal electricity generation mix over time [205]

A notably positive trend in the country is the change from coal towards a “cleaner” gas in the fossil fuel share illustrated *Figure 6-6*. [207].

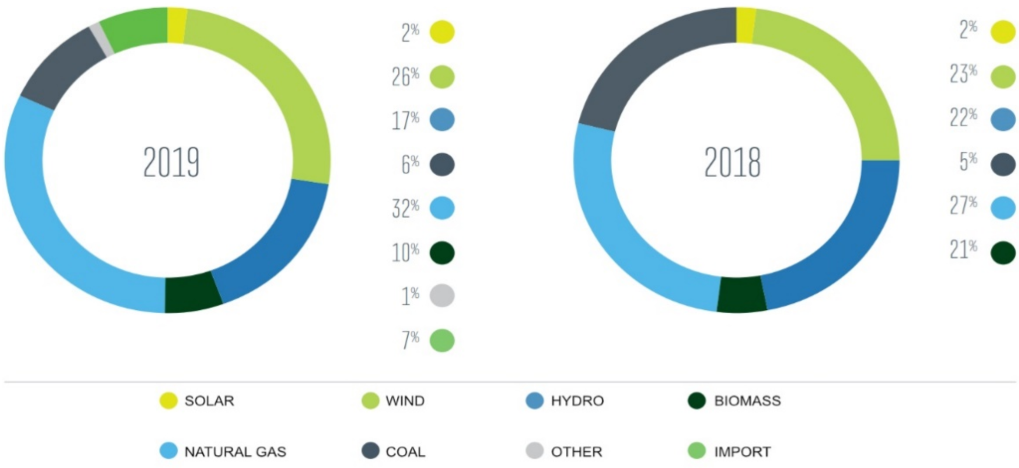


Figure 6-6. Comparison of electricity generation mix of 2018 and 2019 [207]

From a more local perspective, wind power plays an important role in the Torres Vedras municipality as well. Within the municipality, there are 12 wind farms with a total of 57 turbines and an aggregated capacity of 112 MW. This corresponds to approximately 260 GWh of electricity generation annually and 600,000€ municipal income. Additionally, an aggregated potential of 650 kWp solar PV is installed in the area, 5 micro wind turbines and two CHP plants [208].

The shares of different final energy use, such as electricity, heat or transport, have not been identified for Torres Vedras at this stage of research. Only the electricity demand per capita provided in PORDATA[23] can give an insight on the energy demand (see Figure 6-7). An 11% decrease in total consumption between 2010 and 2017 is observed [209]. However, since 2013 the demand had an increasing pattern. This occurred despite Torres Vedras experiencing a slight decline in population over the last years [210]. Non-domestic consumption, which refers mainly to offices/services did not change much over the 9 years. Industrial electricity consumption declined until 2015 and then rose again. Thus, it can be assumed that the initial decline is not due to efficiency improvements, but rather due to fluctuations in the industrial activity.

Notable is the decrease of consumption by public buildings by around 70% [211]. This indicates a need for further research investigating on whether this change is related to efficiency improvement measures to meet the pledges on reducing CO_2 emissions or other issues. For example, in 2010, under the Covenant of Mayors network, Torres Vedras committed to reduce its CO_2 emissions by 20% until 2020 in relation to 2009. Already in 2014, the municipality reached a CO_2 emission reduction of 17% by emitting 326.9 kt of CO_2[24] [212]. Although, the total electricity consumption per capita increased slightly after 2014 (Figure 6-7), this does not necessarily need to go hand in hand with a CO_2 emission increase. In fact, this could even mean the opposite, if the electricity generation has a high renewable share and the increase is associated with the electrification of previously emission-intensive activities, such as transport.

[23] the Database of Contemporary Portugal
[24] There is no recent data indicating if the 20% goal has been achieved.

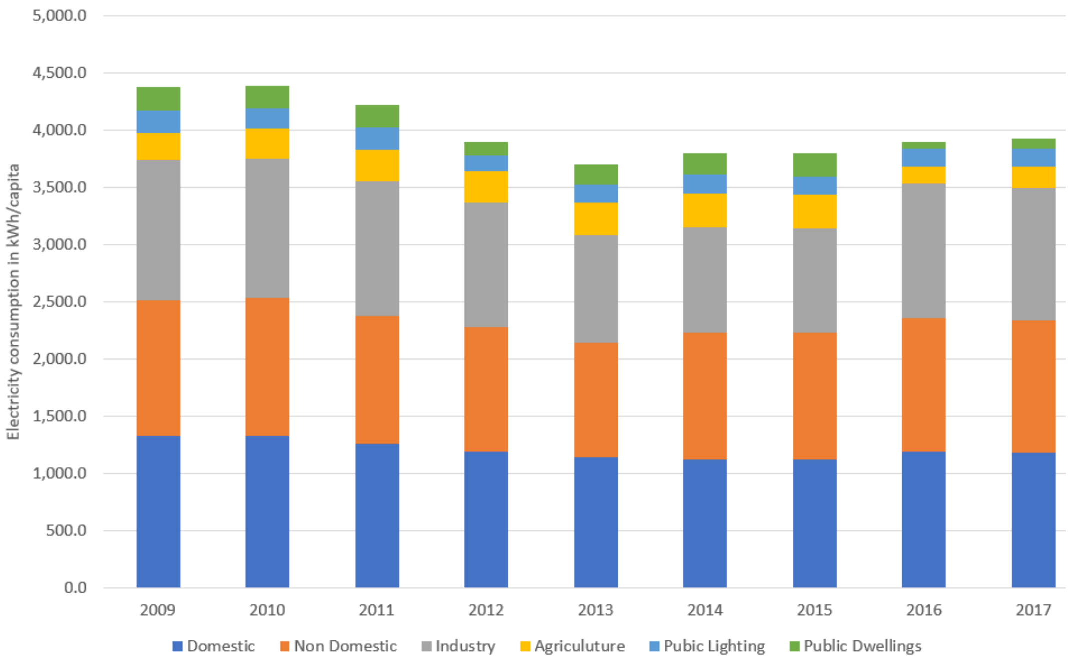


Figure 6-7. Electricity consumption per capita of the Torres Vedras municipality [211]

6.4 Mobility and the Transition to Sustainable Mobility in Torres Vedras

The modal split in Torres Vedras experienced a drastic change between 1991 and 2001. Active modes, such as walking, declined from 49% to 30%, while the share for private cars grew from 33% to 55% [213]. The transportation sector had the highest energy consumption (34% in 2009) [214]. However, recently the municipality has started to change the situation and is actively transforming its infrastructure and encouraging people to shift towards sustainable options.

6.4.1 Active modes of mobility

The **modal share** of walking trips in the municipality is on average 28% [215]. However, in some parts of the municipality, like the parishes of Ponte do Rol and Ramalhal, it is over 40% [215]. In fact, intra-parish trips there represent around 63% of the overall resident trips [215]. However, there's a significant share of short-to-medium distance journeys made by car (42% of trips lasting up to 5 min and 54% of trips lasting up to 10 min) [215]. This demonstrates that there is still a potential for transferring those trips from motorised to active modes. Thus, the Municipality of Torres Vedras has been promoting actions that contribute to boosting modal switch, which are described below [215].

The Sustainable Mobility Awareness Plan includes some concrete steps to promote **walking**. For example, the Metro/Minute Map of the City of Torres Vedras was created [216]. It includes distances and average walking times between the main landmarks of the city using pedestrian streets, sleepers, crossings, staircases, which can shorten the path between city services. Furthermore, a set of awareness-raising campaigns have been realised: for Road Safety, for Disciplined Parking, and safe driving, cycling and walking for Seniors [217]. In addition, other measures include a promotional film that addresses several projects within the Strategic Plan of Urban Development [217], the installation of the arrival and confluence stops, the installation of road information systems in real time; the installation of intelligent traffic control systems; the extension of the city's bike-sharing scheme; and the construction of the Torres Vedras urban cycling lane network [218].

The latter two actions to encourage **cycling** encompass specifically:

- the implementation of an urban bike sharing system – Agostinhas – with 19 stations and around 844 users;
- the construction and renovation of structured cycling network in the city – total of 12 km;
- the creation of bike lanes around territories of environmental and urban interest (e.g. Barro, nearby beaches, Rio Sizandro);
- the amendments to the National Highway Code from 2013 that give some priorities to cyclers [215] [219] [220].

6.4.2 Public transport

Public transport within the city consists of the bus fleet operated by the Barraqueiro Oeste - called TUT[25] [215]. It currently has 4 lines. In one of those lines – the Blue Line – electric buses have been tested since Autumn 2019 [221].

A step to encourage people to use public transport was the building of 12 new bus stops in strategic locations of the city, where significant volumes of passenger transfer occurs [222]. These stops are built by considering accessibility conditions for users with reduced mobility and are equipped with private bicycle parking (to aid intramodality), device chargers, and Wi-Fi [222]. Furthermore, the Barraqueiro Group will test the operation of an "opportunity charging solution" [221]. This type of fast charging between circulations allows extending the operational autonomy of the vehicle, reducing the penalty of efficiency, weight and investment associated with "traditional" electric vehicles with equivalent autonomy [221] [223].

Inter-city transportation consists of buses run by various operators and a train run by the state-run company Comboios de Portugal. About 1,800 people commute daily from Torres Vedras to Lisbon on public transport and around 3,400 on individual vehicles [224]. Torres Vedras has been making efforts to reduce the price of public transport passes to guarantee equal treatment for citizens who commute daily between NUT III do Oeste and the Metropolitan Area of Lisbon (Western Line). Thanks to the Tariff Reduction Support Program 2020 (PART), the price of an interregional pass between Torres Vedras and the Lisbon Metropolitan Area has declined [225]. The Association of Municipalities of the West (OesteCIM) continues to negotiate with Comboios de Portugal and the other intermunicipal communities in order to achieve "more advantageous" solutions for its users [225].

6.4.3 Motorised private transport

The number individual cars travelling each day to Lisbon is almost twice the number of people who go by public transport. Moreover, the share of short-to-medium trips by car leaves room for improvement. The measures that aim at restricting and regulating the use of private motorised transport in Torres Vedras include the new traffic circulation rules, parking rules and speed control devices. Firstly, the municipality created a map showing traffic directions and conditions (e.g. streets restrict to a specified vehicle type), as well as 30km/h zones [226]. Secondly, the Municipality of Torres Vedras regulated the parking, loading, unloading and removal of abandoned vehicles after discussing it with public [227]. Parking zones in Torres Vedras are planned considering the categories of users (for disabled, residents, merchants, visitors). These are communicated on the website of the Municipality devoted to Mobility [228] [229]. The last measure is the installation of 47 speed camera, bicycle and pedestrian detectors and origin-destination sensors at strategic points in the city [222]. They show their speeds to the drivers in real-time, thus making them aware of responsible driving.

[25] A smaller branch of the largest private collective bus passenger transport company in Portugal (Barraqueiro Transportes, SA) [246].

Additionally, they provide information to the municipality that will allow better planning of traffic networks in and around Torres Vedras.

Finally, the municipal government decided to replace its own fleet with EVs. Seventeen EVs (12 light passenger vehicles and 5 vans) are planned to be leased over 4 years [230]. To support the use of EVs, 7 charging stations are available in Torres Vedras with a total of 14 connectors (Figure 6-8) [231]. All of them are built within the nationally funded program MOBI.E [232].

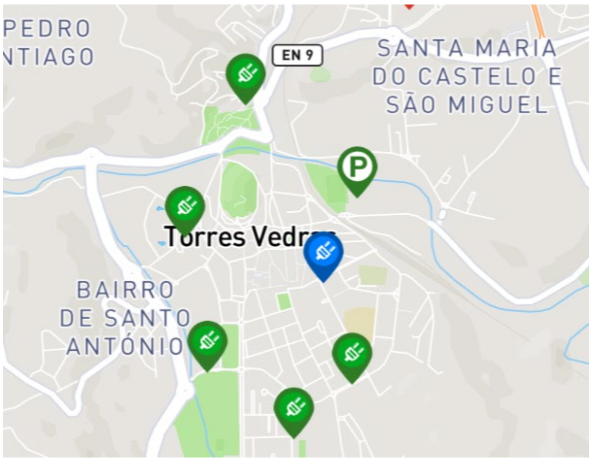


Figure 6-8. Charging stations in Torres Vedras [232]

6.5 Concluding Remarks

The city council of Torres Vedras has demonstrated a continuous and remarkable commitment to decarbonise its economy and transportation. Aiming at reducing its carbon emission by 29% and electricity consumption by 21% by 2020 compared to 2009, Torres Vedras is pursuing a large variety of actions. By active involvement in the European networks, such as CIVITAS, Covenant of Mayors and Hyer, the municipality gained recognition for its sustainable Mobility plan, won the European Green Leaf for its sustainable efforts and secured necessary funding. The Strategic Plan for Urban Development of Torres Vedras, ratified in 2015, serves as the main guideline to achieve the set goals. The focus thereby is on three areas – urban mobility, built environment and disadvantaged communities.

Urban mobility is undoubtedly the sector with the most achievements. The local administration is actively changing the previously established car dependency of the local citizens by facilitating the use of active modes and creating a cycling and walking culture in the community. It starts with teaching kids how to use a bicycle and expands to introducing a bike-sharing system, creating new bike lanes and providing easy-to-read information on walk distances between the important locations in the city. Furthermore, the local public transport company is currently testing electric buses and strengthening the bus network with the addition of new bus stops. The impacts of these measures are to be reflected in the behaviour of the growing generation in the upcoming years, as well as in better air quality.

The actions in the area of urban reconstruction and renovations are mainly focused on adapting public spaces to the social needs of citizens and changing the functions of old buildings to match the interests of the local community. At the same time, a large portion of the activities are directed towards improving quality of life and connecting citizens with nature. To realise this, the municipality invites citizens to participate in the decision-making and planning processes. All this shows that the pathway taken by Torres Vedras in transforming its economy and infrastructure towards a sustainable one is democratic and socially-oriented.

In relation to the dimensions studied within this work, the framework conditions for developing PEDs in Torres Vedras can be summarised with the following diagram (Figure 6-9).

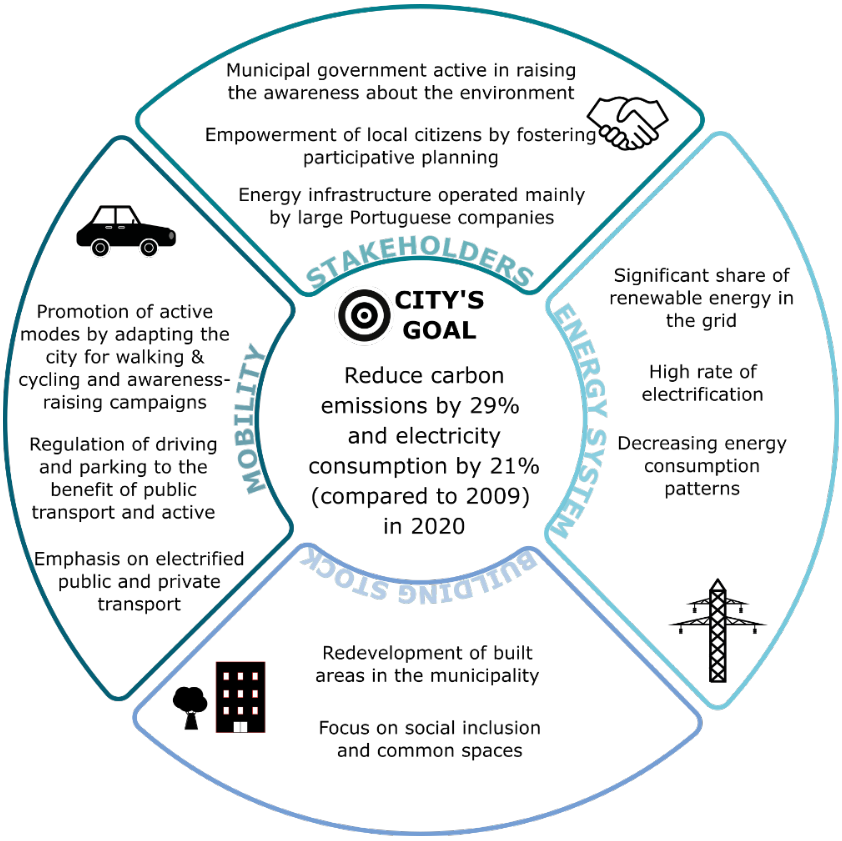


Figure 6-9. Summary of the framework conditions for establishing PEDs with respect to the analysed dimensions – Torres Vedras

7 Conclusion and Outlook

This report describes four cases for which in a later stage of the project more detailed techno-economic analyses are planned. In order to provide a systematic description of these case studies, a concept of framework conditions, defined as the context that frames the development of potential PEDs, has been applied. Structuring these framework conditions along 5 dimensions serves to guarantee a consistent and comprehensive, but also clear and simple, analysis of this context, namely (1) Policy Framework – regulatory, planning and coordination context, (2) Built Environment – building stock conditions, (3) Energy System – energy supply and consumption, (4) Mobility and the transition to sustainable mobility and finally the cross-cutting dimension of (5) Stakeholders.

The cases show different starting points and priorities of municipalities in the transition towards PEDs, but also similarities. First of all, **none of the cases has an explicit focus on Positive Energy Districts yet**. The current policy frameworks and actions do not include PEDs as a cornerstone of achieving full decarbonisation. This might be due to the fact that the term and concept of PEDs is relatively new , which is only recently being thoroughly promoted and explored by a small number of initiatives (e.g. SET-Plan, Smart Cities & Communities (SCC) programmes). That said, all municipalities have a strong focus on climate protection, sustainable development and decarbonisation targets of the most carbon-intensive sectors in general.

Clear and ambitious climate and energy transition targets and plans are defined for all cases. These are defined in relation to whole municipalities, with **no specific targets set for individual districts**.

However, the lack of an explicit focus on the concept of PEDs or, in general, on districts does not mean that PEDs will not become a key approach to achieving an energy transition in the considered cases. On the contrary, **synergies and similarities have been identified between the current actions towards achieving sustainability targets and the steps necessary towards the emergence of PEDs**. For example, Passive building resolution introduced by the government of Frankfurt, climate protection areas in Vienna, reducing the need to travel in Nottingham, and promotion of cycling in Torres Vedras are all good practices that provide the ground for a potential future implementation of PEDs in these localities.

The different needs and challenges in each city identified through discussions with representatives from the municipalities and review of the corresponding literature has identified significant differences in their focus dimensions. The over-arching context for policymaking within the four case studies is that each city or district ("locality", for short) is using, or is proposing to use, a range of policy instruments to deliver on a range of policy goals or targets, across similar sectors in need of decarbonisation – buildings, energy systems and mobility. We thus have a similar set of "policy ends" identified in each case study locality; but different localities have given different weightings to the different policy ends. They are also employing a range of, sometimes quite different, "policy means" to achieving those ends, specifically different mixes of policy instruments [233] [234]. The question is, from this initial review of cases, is there any evidence to suggest the differences have arisen as a result of different local policymaking contexts? The preliminary answer would appear to be "quite possibly".

All local policymaking structures operate within a **multilevel governance (MLG) structure** – in particular in relation to national governments. Our four case studies, however, represent two distinct alternative MLG contexts. The City of Nottingham and the District of Torres Vedras possess at least some policymaking powers independent from the national government which, the case studies have shown, are implemented largely locality-wide. On the other hand, Griesheim and Rothneusiedl are districts within cities (Frankfurt and Vienna, respectively). As a result, these case studies have shown that in each of these districts, the "local" authority is limited in scope.

This **difference has manifested itself in significant ways**. In both Nottingham and Torres Vedras, policies have been implemented or are being prepared, that reflect a degree of local autonomy that has allowed them to develop local responses across the range of local building, energy and mobility challenges. In the Nottingham case in particular, this is located within a coherent over-arching local plan for carbon neutrality, the success of which requires decarbonisation across economic sectors and activities. Torres Vedras, meanwhile, has been able to extend national policies and adapt them to local conditions, but again across a range of activities. In contrast, both Griesheim and Rothneusiedl have had a more subordinate role in local actions. Griesheim is focusing on buildings and urban renewal, whilst in Rothneusiedl the focus is more on reducing buildings' energy demand and on transport. It cannot be inferred from this that one or the other model is superior, because the different policymaking structures differ for valid reasons between two large cities on the one hand and, on the other hand, a smaller city and a smaller district. That said, the evidence presented for Rothneusiedl and the question of getting connected to city-wide improvements in U-Bahn and bus networks highlights challenges for localities that might have limited representation in the city-wide context.

Participation of citizens in local decision-making is one of the key aspects of governance in each case studied in this report[26]. All citizens are invited to express their thoughts and suggestions whenever major initiatives in the selected categories[27] are planned. Among the studied cases, we could see various forms of citizen engagement processes. In the case of Frankfurt and Vienna, there is a structured bottom-up process with official workshops with citizen representatives and stakeholders. Torres Vedras has a centralised approach, where citizens are invited to participate via, for example, a contest. Nottingham municipality reaches out to residents through thematic priorities, as in the case of activities related to energy poverty.

Different localities have also adopted widely **differing policy instrument mixes**. For example, Nottingham has the ability to implement a policy – the Workplace Levy – that has given it fiscal independence for decarbonising transport, even in a country with a highly centralised "fiscal federal" structure. What is common to all cases, however, is that given their relatively small scale, they have been able to implement policies and actions supported by local citizens' engagement in co-creation and operation. Thus, as the research project develops, reflecting on local policymaking contexts will continue to be vital, in terms of policy design, instrument design, and policy implementation.

Differences also occur on the institutional level and the stakeholder setting. E.g. in the two German-speaking case studies ("Griesheim-Mitte" and "Rothneusiedl") the energy related stakeholders are organised under the so-called "Stadtwerke", which sometimes include mobility services. On the other hand, in Nottingham for example, the entities responsible for electricity distribution, energy generation and district heating are distinct. There might be different benefits and drawbacks in each of these stakeholder structures. The main insight so far is that these differences should be accounted

[26] According to the Directive 2003/35/EC, public participation in decision making is mandatory in all EU countries for decisions regarding environmental issues [235].
[27] See Participatory and Procedural Rights in Environmental Matters: https://ec.europa.eu/environment/legal/law/3/module_3_6.htm

for in the planning and implementation of PEDs. These discussed similarities and differences are summarised once again in Figure 7-1.

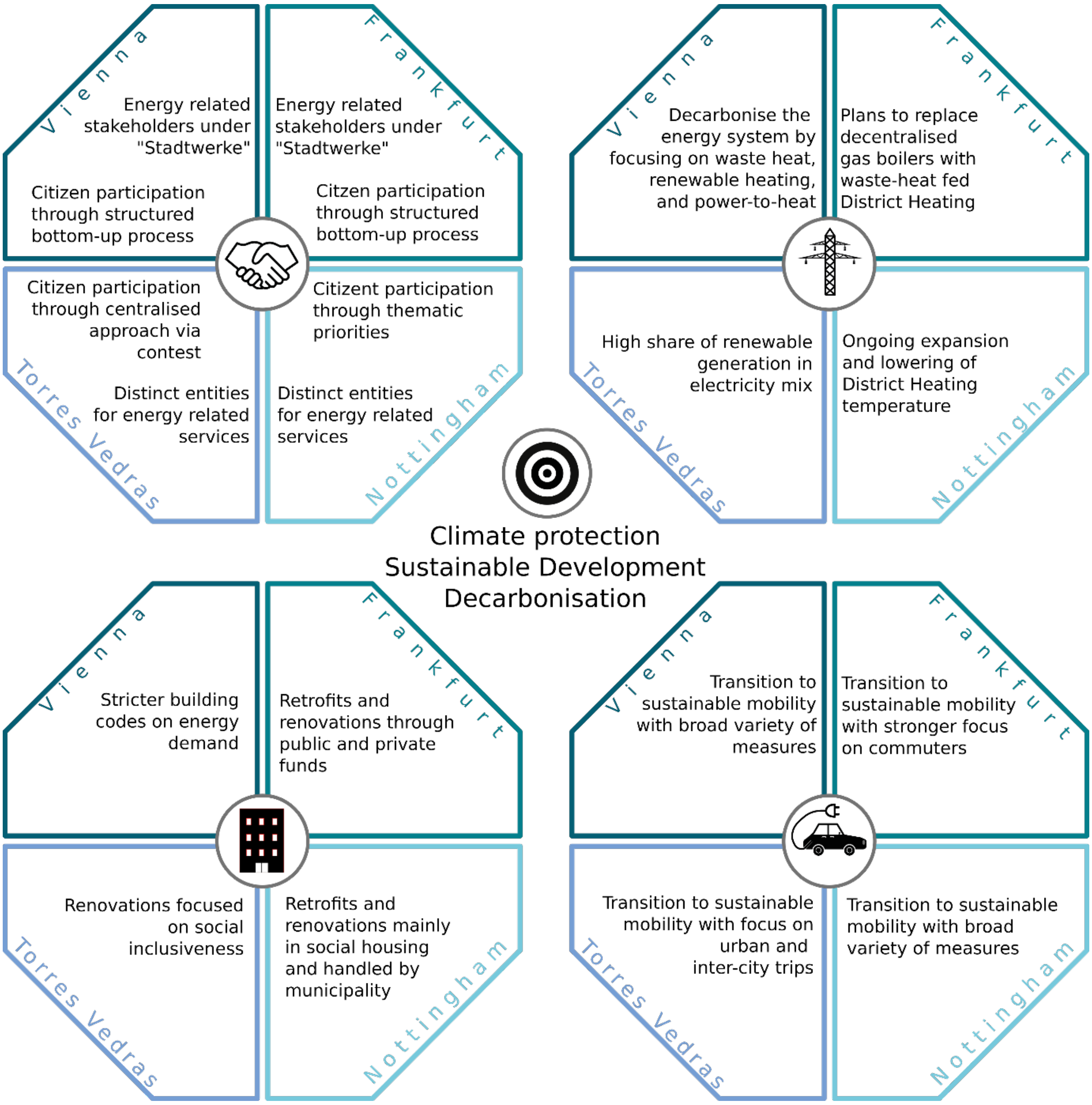


Figure 7-1. Framework Conditions for future PEDs in the four case studies

All actions taken in recent years are essential and provide fertile soil for PEDs growth. However, in the years to come, it will become increasingly important to have a more integrated and multidisciplinary approach to the decarbonisation process. Increasing the EV fleet alone will not be enough if the electricity does not come from renewable energies. Electrifying the heating system is essential, but careful considerations must go in the building stock to lower heat demand and shift heat loads in order to put less strain on the grid that will already have to take care of electric mobility from renewable energies. Hence, from a technical standpoint, it is clear that **a holistic view of the system will become increasingly necessary**.

As this document highlights, each one of the dimensions does not live separately, but they are closely related and influence one another. This connection between the dimensions is the reason for the interdisciplinary approach of the Smart-BEEjs project in analysing PEDs. Each author of this report will **develop a techno-economic model** to explore some of the different aspects discussed in this report within the following two years. The models will dig deeper into the dimensions that compose this document and will also offer potential for integration with each other.

The main topics of further analysis will be the role of **district heating, optimisation of multi-energy micro-grids and the study of policy effects and stakeholder interactions through an Agent-Based Model** (ABM). Of course, all three models will focus specifically on PEDs, but they might apply to different areas as well. There is considerable potential to utilise each model in one of the selected case studies in this report, according to the different focus area each municipality has. For example, the representatives of Frankfurt public authorities are more interested in the decarbonisation of the heating system and exploitation of the waste heat generated by the local data centre for the case of Griesheim-Mitte. For this reason, the case of Griesheim-Mitte is a good candidate to become a case study to be analysed via district heating modelling. In addition, the case is potentially interesting for studying what role policies and stakeholders play in the transition of the existing district into a PED, which is a focus of the abovementioned Agent-based Model.

On the other hand, a multi-energy microgrid model might be more suitable for the case of Vienna, where no exact plan of the new quarter is proposed yet, making it a blank canvas. It will be interesting to explore how different policy interventions will affect the cost-optimal constellation of distributed energy generation in the district. Additionally, to encompass the whole spectrum of energy services within the PED balance, sector coupling with heating and cooling and potentially transportation will be needed.

At this stage of the research, it is possible to give an overview of what the models will accomplish but not of how they will work exactly and what data they will require. Nonetheless, Appendix C provides a generic overview of the two latter elements to offer an idea of the extent of work that lies ahead.

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Appendix A. Case Study Selection

This report provides the evaluation of representative cases studies in the selected European municipalities, which showed willingness of collaboration with the Smart-BEEjS project. While the project collaboration was the major motivation for usage as a case study, “representativeness” of European districts had to be assessed as well, to assure a diverse picture of available districts. Therefore, the essential characteristics of districts and neighbourhoods should be described, and an initial typology of districts should be proposed. On the one hand, this will help to avoid such situation when all districts are of same or similar characteristics, which would bring little value to this study. On the other hand, it will be possible to see clearly, which “types” of districts were encompassed in the current analysis and which ones are left for further investigation. Due to the time and scope constraints, it was not feasible to cover all types of districts in this report.

The economic, socio-cultural, and climate-related diversity of European cites makes it difficult to make general implications, especially when it comes to urban elements, such as cities or districts. For example, due to this reason, the current Reference Framework for PED presented in the Whitepaper by JPI Urban Europe [5] emphasizes that a definition of PEDs should not be “an algorithm for calculating the input and output of energy”, but rather outline the most important functions and requirements for such PEDs. However, the following features of districts can differentiate and influence the definition, emergence and deployment of PEDs.

Climatic conditions

Figure A-1 divides Europe in 4 major climate zones, namely northern, central and eastern, western as well as southern areas. Climate conditions have been selected to be important as they strongly influence the energy consumption as well as the renewable generation potential. Thus, it can be exected that PED project will need to focus on completely different aspects within each climate zone. While this report covers all areas despite the northern areas Alborg is another partner city of the project and might be subject of further modelling activities.

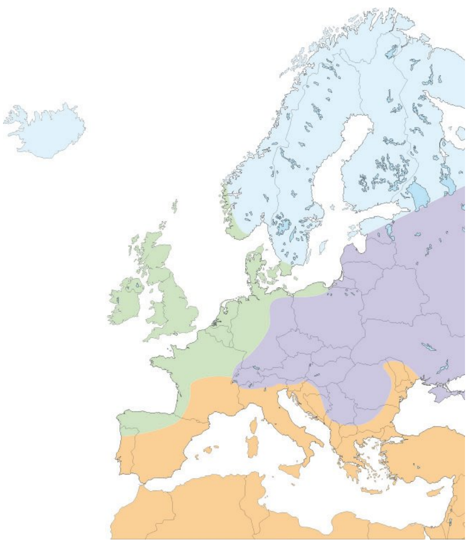

Figure A-1. European climate zones [235]

Status of the district

Another important criterion is if the district is already existing, it is already existing and PED-like or if it is planned as a completely newly developed area. While the latter holds true for Vienna’s case study, Griesheim-Mitte in Frankfurt would be an already existing district that is not PED-like. Thus, a PED-like district would be interesting for assessment. As Nottingham has not settled on a specific district yet, in this regards the SCENe project district in the Trent Basin could be chosen to have a PED-like district included in the analysis. With PED-like we refer to districts that are already far developed in terms of DERs but do not fulfil the PED criteria yet.

Population density

Finally, also the population density plays an important role as it determines the available space for DERs and in addition the aggregated district energy consumption that needs to be covered. We separate among three population patterns:

- High: High population density districts can be found in urban areas with multi-storey apartment buildings and are most likely defined by a high energy consumption / available space ratio. This high ratio is likely to influence a PED creation negatively.
- Medium: Medium population density districts are in between and most likely suburbs of big cities or districts in medium sized towns. (Energy) economic considerations
- Low: Low population density districts are those that can be found in rural areas such as villages, where distances between buildings is much higher and often unused space can be found. Additionally, houses are more likely to be one-family houses. This decreases the energy consumption / available space ratio and therefore increases the likelihood for a successful PED implementation in the energy sense

Griesheim-Mitte would be classified within Medium population density. Even though Rothneusiedl is not a developed district yet, it would most likely fall Medium population density as well due to its very suburban character. Thus, to complete the picture, a very high population density district would be needed as well as a rural, very scarcely populated district.

Other

Other ideas regarding district typology are according to GDP or energy price related indicators, which however have not been assessed in this work.

Appendix B. Vienna Further Information

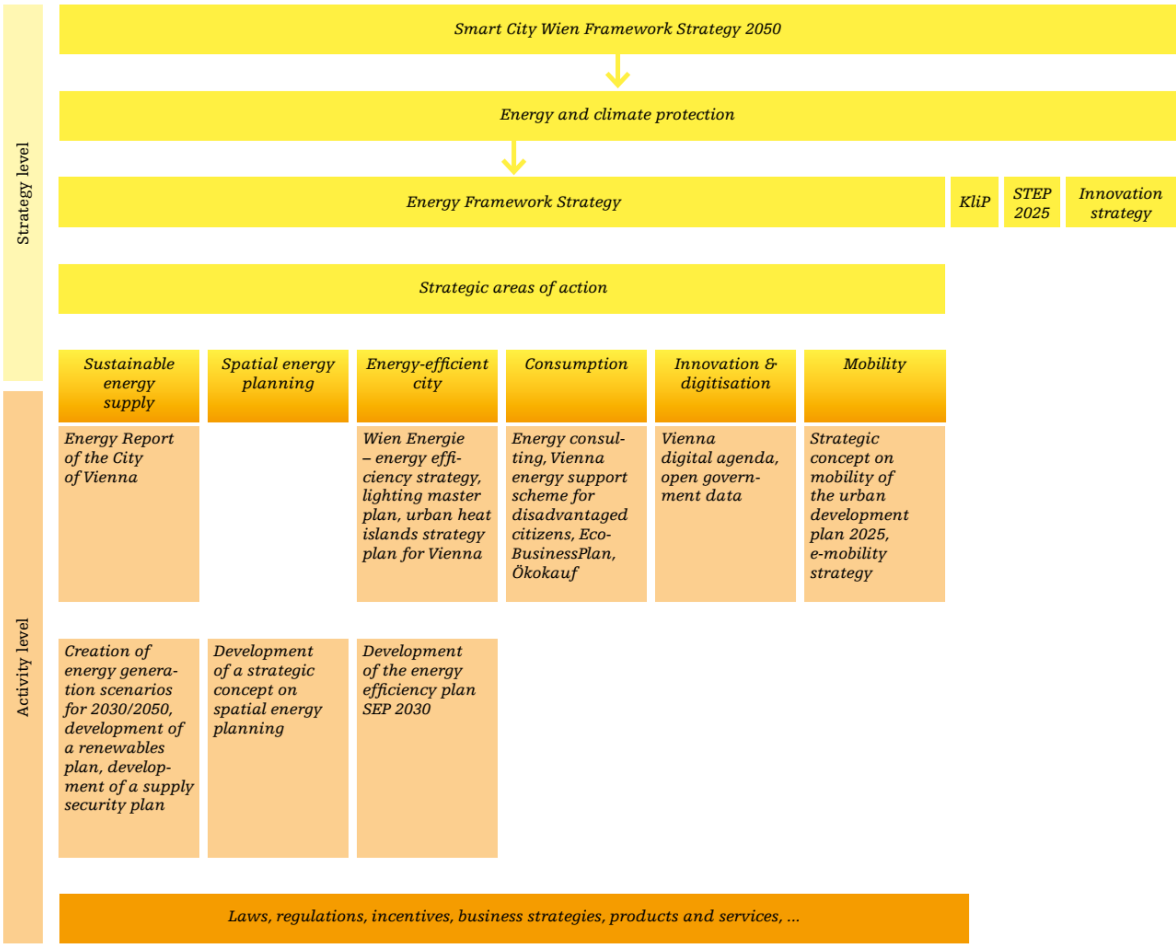

Figure B-1. Vienna's framework strategies [134]

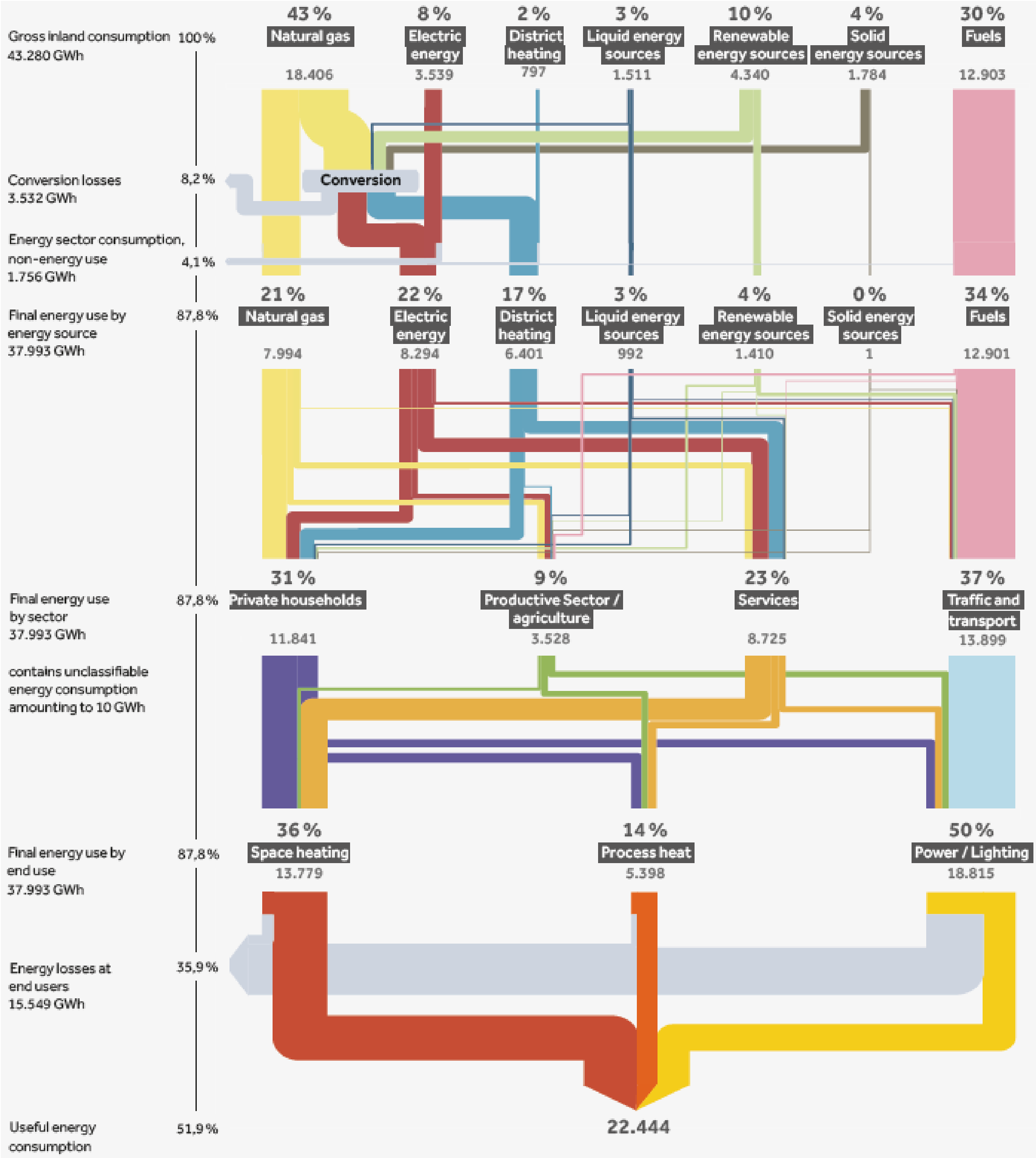

Figure B-2. Vienna Energy Flow Chart 2018 in GWh [138]

Appendix C. Data considerations for future work

Analysed dimensions	Source of available data	Necessary information	Purpose of use	Open questions
Policy Framework				
Current goals and targets	Government website and strategy documents	Future/provisional goals	To make sure the actual goals and modelled outcomes are aligned	Is there a possibility to add decentralised goals and targets at district level (not only at city level)?
Financing	Government webpage, strategy and relevant project documents	Financing options for specific technology types (e.g. for building insulation or renewable heating)	The source and amount of financing influences the model scenario, e.g. stakeholders and their level of involvement	If and how will the financing issues be included in the model?
Specific policies	Government website, www.res-legal.eu	Specific policies regarding technology types to be modelled (e.g. for building insulation or renewable heating)	To test the effect of policy interventions by integrating existing and future policies	Which specific policies (regulations, monetary instruments) will the model represent?
Building Stock Condition				
Energy efficiency of the building stock	Energy demand by building typology available for Nottingham and Frankfurt	Information about the age, type, and energy demand class of industrial, commercial, and public buildings	Energy efficiency of buildings influence energy demand values; needed for sensitivity analysis.	What specific measures, and by how much can they improve the energy efficiency of each building typology?
Building types by function (end-use)	Available for Frankfurt, only residential buildings data are available for Torres Vedras and Nottingham	Function of buildings (e.g. residential industrial, tertiary, public buildings), spatial data	End-use type of buildings defines the energy demand profile and energy density.	To what extent does the function of buildings play a role in reducing the energy demand in the neighbourhood?
Population density	Statistical data available	Spatial data on population density (by district)	To estimate key indicators, e.g. energy demand per capita	How to ensure "positive energy" in densely populated parts of a district?
Energy Supply				
DERs and conversion technology	Various sources of information (some data from project deliverables, Grid operator websites)	Centralised information on the renewable power plants – e.g. in a database or GIS-system (types, location, capacities, etc.)	Capacities of existing local renewable generation (by type) are input data for the model	What policy interventions encourage the adoption of DER technology?
Non-renewable generation	Municipal reports, grid operator websites	More recent generation by fuel type; finer temporal resolution	Capacities of generation plants are input data for the model	What policy interventions discourage the use of non-renewable generation?
District heating	Website of a corresponding district heating operator	Plans for the extension of the DH network, supply temperatures; spatial data.	To estimate cost of transition to DH; for sensitivity analysis.	How will the agents connected to district heating be represented in the model?
Energy Use				
Final district or city energy consumption by end-user	Annual consumption data from various sources of information	More recent energy consumption data (per building, district, or total); with finer temporal resolution.	To calibrate the model or validate energy demand estimation (per household, per building)	If there is a difference in the energy consumption between different end-user types, wat is the reason for that?
Outlier consumers	Not identified	If exists, data about outlier consumers	To evaluate possible energy recovery solutions.	How shall outlier consumers be represented in the model (if at all)?
Stakeholders				
Local government	Identified, from government website	-	-	What is the role of the local government agent in the model (active vs. passive)?
Residents	Demographic data openly accessed	Information on household types (1-, 2-, 3-people household, income, education)	Necessary for representing household agent decision-making in the model	What are the main factors that make people consume less energy?
Energy system stakeholders	Identified, from various sources	Future expansion plans, business models	Necessary for representing energy system actor decision-making in the model	How to simplify the real-life heterogeneity and interactions of the stakeholders in the model?

Glossary

Car sharing (or carsharing, car-sharing)	one of the forms of shared car use, similar to carpooling and hitchhiking. With car-sharing the same car is used by several people in turn at another time. Car-sharing differs from standard car rental because car-sharing assumes a commitment to regular use and availability of the car [236].
Car pooling	a form of shared car use, when a car used by several people together at the same time [236].
Detached houses	a typical British house type, also known as single family house. It usually has a ground floor and a first floor, but it may vary.
Energy vector (or energy carrier)	"… allows to transfer, in space and time, a quantity of energy" [237].
Final energy consumption	the energy utilised by the end users. It does not keep into account energy used by a particular sector, losses, energy transformation, etc.
Intermodality	relates to improving the efficiency and attractiveness of a single trip made with more than one transport mode (e.g. walking, train and bus), with the aim of offering travelers a seamless journey (not to be confused with multimodality).
Modal split, modal share	the share of people using a particular mode of transport (including cycling and walking) within the overall transport usage of an urban area [238].
Motorised vehicles	any road vehicle driven by an engine.
Multi-energy	involving electricity, heating and potentially more types, such as cooling. Encompasses more than one energy demand by service.
Passiv house standard	a building or a house that uses very little energy. As defined by the International Passive House Association, it must not exceed 15 $kWh/m^2/y$ or 10 W/m^2 for peak demand. Similar cooling demand adjusted for dehumidification needs according to the area. It must not exceed 120 $kWh/m^2/y$ of primary energy for usable living space. A maximum of 0.6 air changes per hour at 50 Pascal pressure and the internal temperature must not exceed 25 °C for more than 10% of the hours of the year [239].
Row/Terraced houses	known also as townhouse in US. It is a house that has both side walls shared with another house (except for the houses that lie at the edges of the housing complex).
Semi-Detached houses	a house that has only one wall shared with another house. It typically has a centre axis on which the building is mirrored. It also has two separate entrances.
Primary energy	the total energy demand of a given area. It covers the energy sector itself, losses for transformation and distribution.
EnergieSprong	a Dutch initiative to make house refurbishment and retrofitting more affordable by creating mass demand for these kind of interventions [240].
Vehicle miles	the total activity of traffic on the road network in Great Britain is measured in vehicle miles/kilometres. Vehicle miles/km are calculated by multiplying the Annual Average Daily Flow by the corresponding length of road [241].

Abbreviations

°C	Degree Celsius
AG	Aktiengesellschaft
APG	Austrian Power Grid
CCHP	Combined Cooling, Heat and Power
CHP	Combined Heat and Power
CO_2	Carbondioxide
COP	Coefficient of Performance
D2N2	The Local Enterprise Partnership for Derby, Derbyshire, Nottingham and Nottinghamshire
DER	Distributed Energy Resource
DH	District Heating
DHN	District Heating Network
DHW	Domestic Hot Water
DNO	Distribution Network Operator
DSO	Distribution System Operator
ERSE	Entidade Reguladora dos Serviços Energéticos
ESCO	Energy Service Company
ESO	Electricity System Operator
ET	Electricity Transmission
EV	Electric Vehicle
FIT	Feed In Tariff
GHG	Greenhouse gases
GHWth	Gigawatthour Thermal
GmbH	Gesellschaft mit beschränkter Haftung
GWh	Gigawatthour
Gwhel	Gigawatthour Electric
HP	Heat Pump
ISEK	Inegrated Urban Development Plan (Integratives Stadtentwicklungskonzept)
ITC	Instituto Tecnologico de Canarias
KEEA	Klima und Energieeffizienz Agentur GmbH
km	Kilometer
kt	kilo tons
kV	Kilovolt
kW	Kilowatt
kWel	Kilowatt electricity
kWh	Kilowatthour
kWp	Kilowatt peak
m^2	Squaremeters
MPT	Motorised private transport
MSW	Municipal Solid Wastes
Mtoe	Mega tons of oil equivalent
MVA	Mega Voltampere

MW	Megawatt
MWh	Megawatthour
MWp	Megawatt peak
NCC	Nottingham City Council
NCH	Nottingham City Home
NTU	Nottingham Trent University
OiB	Österreichisches Institut für Bautechnik (Austrian building engineering association)
PED	Positive Energy District
PEF	Primary Energy Factor
PV	Photovoltaic
REN	Redes Energéticas Nacionais
RES	Renewable Energy System
SCENe	Sustainable Communities Energy Networks
SEG	Smart Export Guarantee
SET-Plan	Strategic Energy Technology Plan
SH	Space Heating
SM	Sustainable Mobility
tCO_{2_equ}	ton of CO_2 equivalent
TSO	Transmission System Operator
TUW	Technische Universität Wien
UK	United Kingdom
ULEV	Ultra Low Emission Vehicles
WP	Work Package

About the Smart-BEEjS Project

Energy transition is supported in the EU by legislative developments, such as the Strategic Energy Technology Plan that aims to transfer power to consumers by decentralising the energy eco-system at the local district-level. However, this transition occurs at a time of increasing wealth inequality, energy poverty, and gender difference. Thus, the long-term vision of the Smart-BEEjS project is **to design transformational pathways** that tackle **Energy Poverty and Justice**, providing evidence and using the decentralised nature of **'Positive Energy Districts'** and **'Networks of Districts'** as the central platform of transformation, whilst recognising the economic, social and environmental challenges faced. Tackling the issue of energy injustice and poverty is an essential pillar for contributing to the **decarbonisation of our economies** without leaving large parts of the population behind.

Behind any decision or intervention – whatever the field of expertise, technological, business or policy – are **people**. Therefore, **the overarching training aim of Smart-BEEjS** is to provide, through a multilevel, multidiscipline and interdisciplinary training platform, a programme to produce the technology, policy making or business oriented **transformative and influential champions of tomorrow**; educated in the personal, behavioural and societal concepts needed to deliver the success of any technological proposition or intervention under the human-centric perspective of energy justice.

The Smart-BEEjS project recognises that the new level of decentralisation in the energy system requires the **systemic synergy of different stakeholders**, who are **inseparable** and interrelate continuously to provide feasible and sustainable solutions in the area of **energy generation and energy efficiency**. They balance attention towards technological and policy-oriented drivers from a series of perspectives:

- **Citizens and Society**, as final users and beneficiaries of PEDs;
- **Decision Makers and Policy Frameworks**, in a multilevel governance setting, which need to balance different interests and context-specific facets;
- **Providers of Integrated Technologies, Infrastructure and Processes of Transition**, as innovative technologies and approaches available now or in the near future;
- **Value generation providers and Business Model Innovation (BMI)** for PEDs and networks of districts, namely businesses, institutional and community-initiated schemes that exploit business models (BMs) to provide and extract value from the system.

In order to introduce cooperation and shared thinking, Smart-BEEjS presents a balanced consortium of beneficiaries and partners from different knowledge disciplines and different agents of the energy eco-system, **to train at PhD level** an initial generation of **transformative and influential champions** in policy design, techno-economic planning and Business Model Innovation in the energy sector, **mindful of the individual and social dimensions,** as well as the **nexus of interrelation between stakeholders** in energy generation, technology transition, efficiency and management.

The overarching aim of the project is to boost knowledge sharing across stakeholders, exploiting a human-centric and systemic approach to design Positive Energy Districts (PEDs) for sustainable living for all.

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