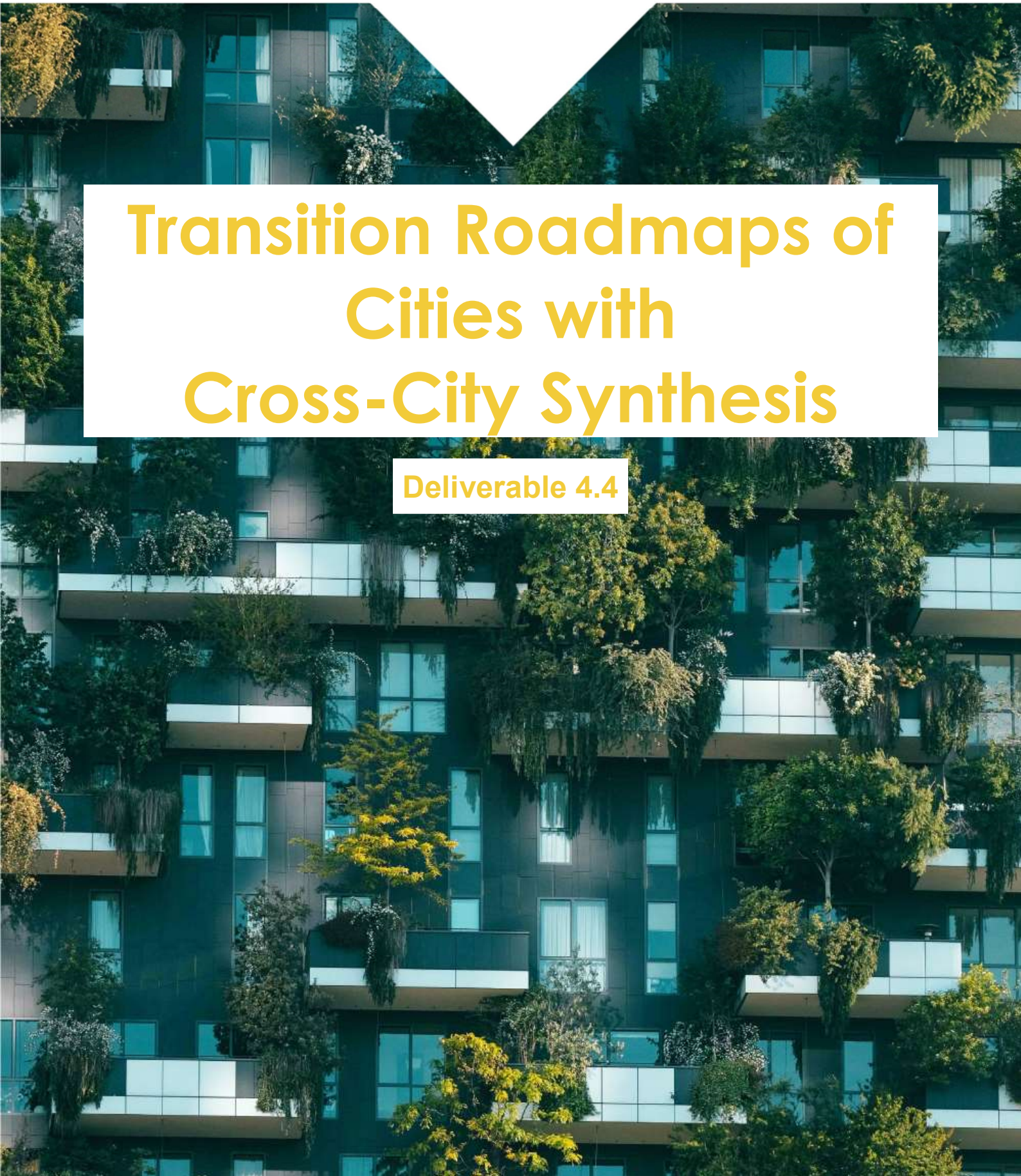
DECARB CITY PIPES 2050



Transition Roadmaps of Cities with Cross-City Synthesis

Deliverable 4.4

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Introduction

In the transition towards fossil-free alternatives for heating and cooling, all cities face a significant challenge in transforming their building stock. The solutions available and the implementation pathways differ from city to city, depending on social, political, economic, and technological conditions.

As part of this project, each of the participating cities – Bilbao, Dublin, Munich, Rotterdam, Vienna and Winterthur – has in the last couple of months created its own **Transition Roadmap**. The role of the City of Bratislava in the Decarb City Pipes 2050 project had to be reduced at a very late stage of the project preparation due to unforeseen internal capacity limits. It was decided that the importance of including an Eastern European city with a long DH tradition remains valuable for the project. For this reason, no transition roadmap was elaborated for Bratislava.

A transition roadmap is a strategic plan that provides a structured and phased approach to guide the transformation of energy systems, industries, or sectors towards sustainability and reduced greenhouse gas emissions in the heating and cooling sectors. The roadmap also serves as a guide for decision-makers, policymakers, and stakeholders to navigate the complexities of decarbonization and achieve the desired sustainable outcomes.

These roadmaps were the final phase of an intense local planning process, integrating previous findings and outlining comprehensive strategies and timelines for achieving energy-efficient and zero-carbon urban heating and cooling.

Along with all six transition roadmaps (see Annex), this report also provides a **cross-city synthesis**, i.e. a summary and comparison of these documents. The purpose of this synthesis is to outline the status in each city and some of the key next steps (actions) being taken to achieve their heating decarbonisation goals. Also included is a summary of the process each city took prior to developing a transition roadmap.

Transition Roadmap Development Process

Working towards actionable Transition Roadmaps

In the context of the H2020-project Decarb City Pipes 2050[1], six cities (Bilbao, Dublin, Munich, Rotterdam, Vienna, and Winterthur) have undergone a progressive and detailed process to envision and plan their transition towards energy-efficient and zero-carbon urban heating and cooling systems. This journey can be divided into three key phases: **Heating and Cooling Outlooks**, **Heating and Cooling Plans**, and **Transition Roadmaps**.

For easier understanding, these key phases can also be summarised into What, Where, When & How respectively, as shown in the figure below.

FIGURE 1: TRANSITION MANAGEMENT KNOWHOW

What: In their **Heating and Cooling Outlooks**, the cities gathered climate and energy consumption data, reviewed policies and analysed trends to understand their current and future heating and cooling needs. They considered the technological and economic

[1] Decarb City Pipes 2050 – Phase-out fossil fuels from urban heating & cooling: https://decarbcitypipes2050.eu/

possibilities and necessities on a broader scale. This initial phase provided a general understanding of what solutions were feasible for their respective contexts. Although still at a higher level, this phase laid the foundation for the subsequent planning stages.

Where: Building upon the findings of the Heating and Cooling Outlooks, the cities then progressed to develop more detailed **Heating and Cooling Plans**[2]. In this phase, they further developed comprehensive strategies to address their individual heating and cooling needs. The plans took into account more specific factors such as spatial considerations, existing infrastructure, building types, and energy demand. By analysing these details, the cities were able to strategically determine the optimal heating and cooling solutions for different areas. The level of detail increased in this phase, as more specific data and factors were considered.

When & How: Finally, the cities created **Transition Roadmaps**, which address the question of what actions to take, where, when, and how. These roadmaps represent the most advanced phase of the planning process. They integrate the findings from the previous phases and delve into the comprehensive strategies and timelines required for achieving energy-efficient and zero-carbon urban heating and cooling. Within these roadmaps, the cities consider policy measures, stakeholder engagement, technological advancements, and other relevant aspects. In essence, the Transition Roadmaps provide a comprehensive guide for implementing the transition effectively.

Each phase of the process allowed the cities to refine their plans and increase the level of detail. The Heating and Cooling Outlooks provided a general direction, the Heating and Cooling Plans used spatial energy planning to provide specified solutions for different areas, and the Transition Roadmaps dealt with the complexities of implementation. With each phase, more details and data were taken into account, enabling the cities to make informed decisions and pave the way for successful transitions to sustainable heating and cooling systems.

The Transition Roadmaps Process

A transition roadmap sets out the steps towards achieving the future vision from a city's H/C Outlook, while also meeting the city's current H/C demands. It is important that the transition roadmap is developed in collaboration with key local stakeholders (local working groups) to ensure that due consideration is given to local conditions and that the actions have the support of those who will be key to its implementation.

The local working group which has been created within each of the participating cities in the beginning of this project is a collaborative entity formed at the local or regional level to achieve decarbonization in a city's heating and cooling infrastructure. Comprised of stakeholders from various sectors, this working group aims to develop strategies, set goals, and implement actions to transition from fossil fuel-based systems to low-carbon alternatives. They engage stakeholders, develop plans, advocate for supportive policies, and oversee project implementation.

[2] https://decarbcitypipes2050.eu/wp-content/uploads/2023/06/D3.3-HC-plans-and-cross-city-synthesis-FIN.pdf

The composition of each local working group in each city is shown in the table below. There are several commonalities across each of the cities local working group institutions. In particular, city council (municipality) and utilities company representatives are critical to enabling the transition. There are also differences in the level at which the working group sits i.e., at a national, regional or local level.

TABLE 1: LOCAL WORKING GROUP COMPOSITION

City	Local Working Group Members
Bilbao	Mobility and sustainability commission, municipal departments and institutions (housing, retrofitting, ICTs, employment...), regional institutions (energy and environment, water, waste...)
Dublin	National gas utility, national electricity utility, city/county council representatives, city energy agency, utilities regulator, national department of climate change, national energy authority, national geological surveys
Munich	Various departments from city administration, utility/DSO (Stadtwerke München), city-owned housing companies, city-owned refurbishment company
Rotterdam	Staff of Municipality Rotterdam, Sustainability Department, DH companies, grid owners (public / private), housing cooperations, politicians (to be involved later)
Vienna	City administration (city councillor officers & municipal departments (e.g., energy department, urban development etc.), utility/DSO, representatives of the building/housing sector
Winterthur	Utility (Stadtwerke Winterthur), building permit department, environment, and health department (city administration), administration of group convenings through an external partner (PLANAR)

During the course of the project, each partner city developed a Transition Roadmap using a variation of the following process.

Below is a step-by-step process used by Dublin with its local working group to create its Transition Roadmap. It is important to note that in addition to the variation in composition of each working group, the nature of the barriers also varied depending on the relevant actors in each of the cities heating and cooling sector.

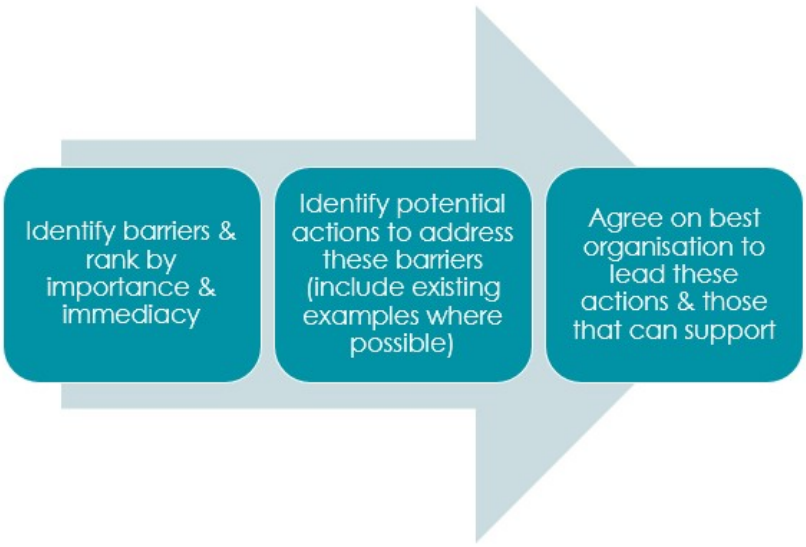


FIGURE 2: TRANSITION ROADMAP (TR) PROCESS

The first step was to **identify the barriers** that would prevent each city from achieving its heat transition targets at the speed and scale required. In order to help facilitate this thought process, the challenges were considered under some of the headings shown in the figure below - political, economic, socio-cultural, technological, environmental, legal (commonly referred to as PESTEL) or through the following categories: knowledge & skills, resources, regulation policy & planning, technology, mindset awareness & engagement, governance structures & authority and other.

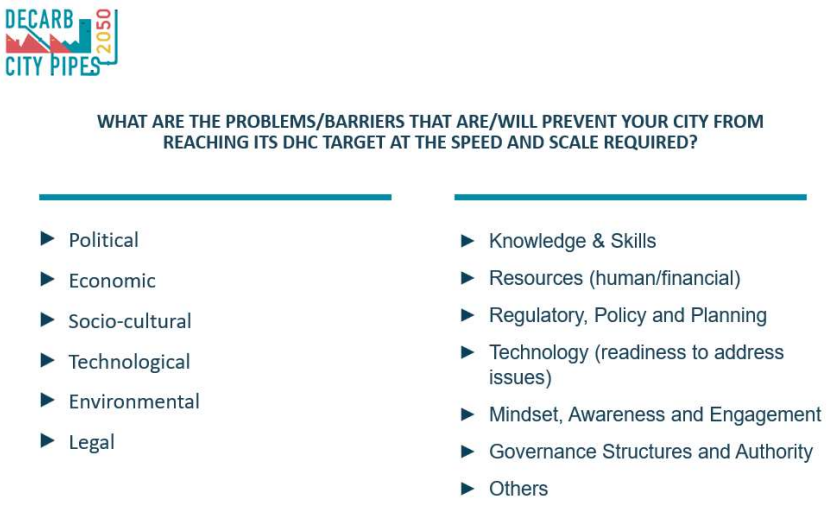


FIGURE 3: PESTEL (POLITICAL, ECONOMIC, SOCIO-CULTURAL, TECHNOLOGICAL, ENVIRONMENTAL, LEGAL)

Following their identification, the barriers were placed into a hierarchy based on their priority and the timeframe in which they should be addressed. The figures below show the matrix used for this process.

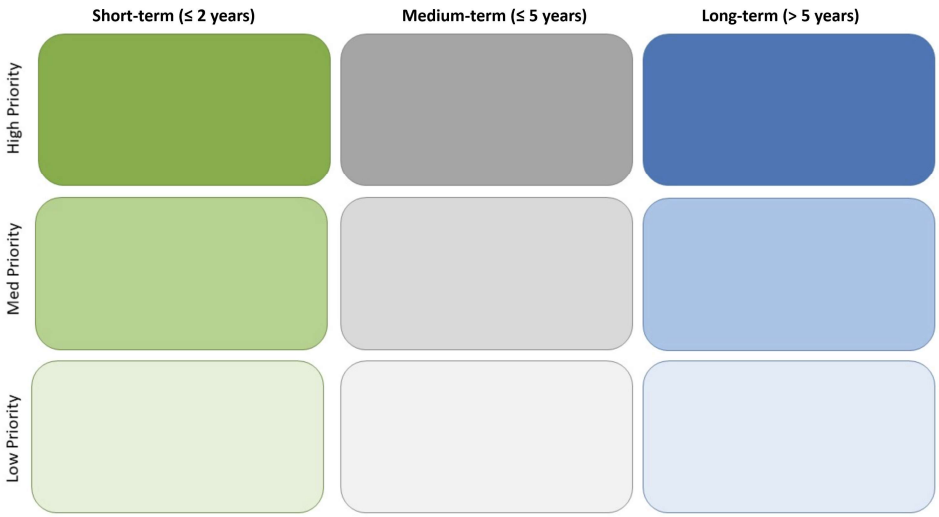


FIGURE 4: TR PROCESS – HIERARCHY MATRIX

Throughout the development, it is important to have local stakeholders involved in this process. This can often be best facilitated through online workshops using tools such as Miro. The images below show a Miro board from such local stakeholder engagement which followed the same process as set out above.

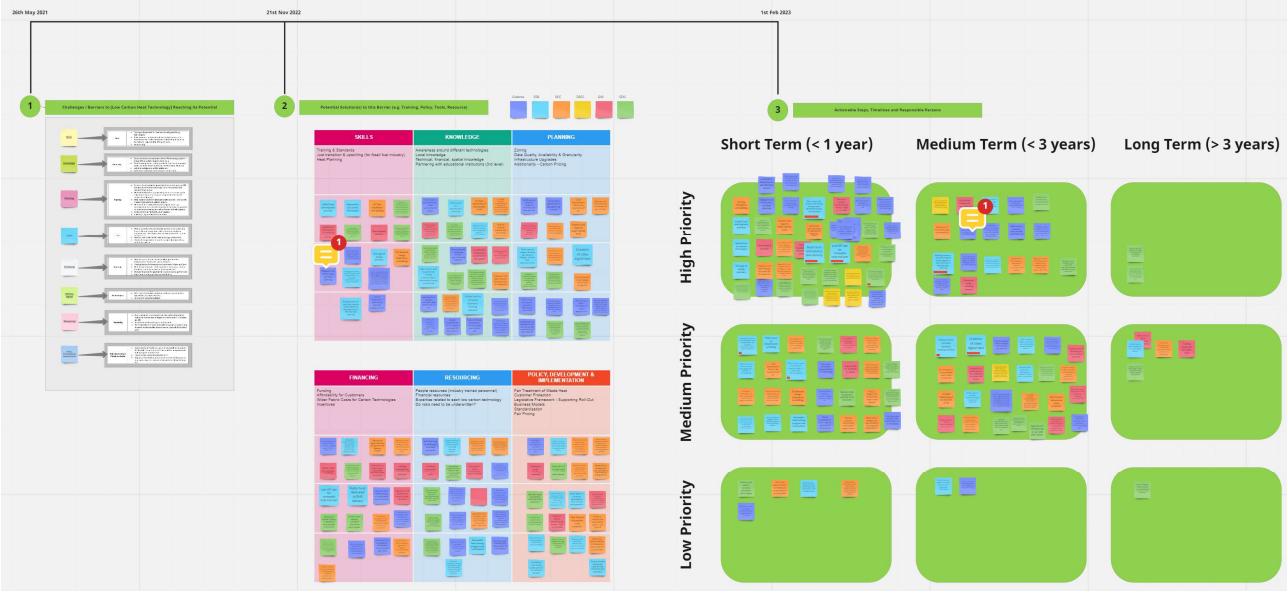


FIGURE 5: TR PROCESS – EXAMPLE OF A LWG WORKSHOP (DUBLIN)

The outputs of these workshops were then used to form an action list spreadsheet. This spreadsheet laid out the actions in the following format. Additional columns could also be added to set out indicators for successful implementation (these should be SMART – specific, measurable, achievable, relevant and timebound) or for breaking down actions in smaller more manageable intermediate steps.

Category	Action	Completion Date	Lead	Support	Supporting Information
See list on right hand side	Describe the action to be taken	Date action needs to be completed by	Organisation responsible for delivery of the action	Organisations that need to provide input	Examples/case studies, useful tools, experiments, resources, etc.

- Knowledge & Skills
- Resources (human/financial)
- Regulatory, Policy and Planning
- Technology (readiness to address issues)
- Mindset, Awareness and Engagement
- Governance Structures and Authority
- Legal
- Environmental
- Others?

FIGURE 6: TR PROCESS - ACTION LIST SPREADSHEET

Outline of the Cities' Transition Roadmaps

Included in the appendix of this document are each of the cities' Transition Roadmaps. No two roadmaps are the same, as each document is developed to consider the social, technological, political, and economic challenges that are individual to each city.

Some of these transition roadmaps have already found political approval within the cities and have already been publicized.

- **Bilbao**'s Transition Roadmap comprises essential information of the heating and cooling sector, considers the barriers and strengths of the city, and exposes the most relevant instruments to accomplish an emission-free H/C sector.
- **Dublin**'s Transition Roadmap was compiled by Dublin's Energy Agency Codema and was produced in collaboration with its local working group (see above). Political approval is yet pending.
- **Munich** lists key levers and strategies for the transition to fossil-free heating and cooling as well as a selection of local instruments. As the city is currently still revising major parts of its strategy for the H/C-sector, its current transition roadmap provides an outlook on current discussions.
- Based on the Climate Agreement in the Netherlands, every municipality had to draw up a "Heat Transition Vision", in which they inform the government which neighbourhoods and homes have the potential to become natural gas-free by 2030. **Rotterdam's** Transition Roadmap is largely composed of this Heat Transition Strategy, which is centred around its WHAT- and WHEN-maps.
- **Vienna**'s Transition Roadmap comprises central parts of (verbatim where translation available) its **Climate Guide**, published in early 2022 (in German "Wiener Klimafahrplan", verbatim "Vienna Climate Roadmap") and which deals with buildings and energy supply, and of its **Heating and Cooling 2040 concept**, published in early 2023.
- Winterthur references its new municipal energy plan that was approved by the city parliament on October 31, 2022 and came into force in early 2023. It is a binding guideline plan that shows in which areas which energy sources are intended for heat supply.

Below, short summaries of each of the cities' transition roadmaps are provided:

Bilbao

Bilbao has undergone a remarkable urban regeneration over the past four decades, transforming from a heavily industrialized and polluted city to a modern hub of advanced services, technology, and knowledge. The city's successful transformation was driven by strategic initiatives such as relocating the harbour, building a subway network, treating the sea inlet, and reconstructing a tram line. Bilbao has prioritized sustainability and energy efficiency, committing to climate neutrality by 2050 through the Bilbao Environmental Strategy. The city has surpassed its previous targets for reducing CO_2 emissions and is now working on the Sustainable Energy and Climate Action Plan 2030, aiming for a 55% reduction in GHG emissions. The decarbonization of the heating sector is a key focus, with measures including energy reduction, building retrofitting, renewable energy integration, and analysis of district heating networks. Bilbao's successful urban governance model and autonomy in urban planning have contributed to its transformation and can also be leveraged in the heating transition.

Its Transition Roadmap provides important insights, addressing challenges, strengths, and necessary instruments for achieving a carbon-neutral heating and cooling sector. It has been elaborated by the municipality in conjunction with Tecnalia, as a consulting entity. The document is approved by the Sustainability Commission in the City Council. It emphasizes the refinement of valuable tools to support the heating transition (energy spatial planning, additional municipal resources, and a legal framework).

Dublin

Heating is a hugely important sector in Ireland when it comes to decarbonisation as it represents approximately 40% of energy demand (twice the demand of electricity) and is the worst performing sector in terms of renewable proportion (currently at 6.3% of total heat production) behind both electricity and transport. Dublin heavily relies on gas-fired heating, with the gas grid covering the entire city. The Climate Action Plan aims to transition all buildings to heat pumps or district heating by 2050, eliminating the use of gas grids. While district heating is currently underutilized, there is significant potential for its expansion, with targets set for heat supply through district heating of 0.8 TWh by 2025 and 2.7 TWh by 2030. The government plans to support district heating through funding, governance systems, research, regulations, and incentives. Dublin has made progress in implementing district heating schemes, such as the Tallaght District Heating Scheme, and is advancing plans for a larger network in the Docklands and Blanchardstown areas. The city is also exploring geothermal district heating and integration with the electricity sector.

Dublin's Transition Roadmap's key outcome is a list of actionable steps, with timelines and responsible individuals to enable its transition. It is written by Codema, its energy agency, with input from the Sustainable Energy Authority of Ireland (SEAI), Department of Climate & Communications (DECC), Dublin City Council (DCC), Electricity Supply Board (ESB), and Gas Networks Ireland (GNI). The document has and will be used as a basis for current and upcoming city development plans to aid the transition to net zero by 2050.

Munich

Space and water heating account for a significant portion of energy consumption in Germany, particularly in private households where it makes up around 90% of total energy usage. Munich, in particular, has a high demand for heating, covering about 48% of total energy consumption, with fossil fuels still dominating the heating sector, contributing to greenhouse gas emissions. Munich has put a strong focus on climate protection, with Stadtwerke München (SWM) playing a key role in the energy transition. The city aims for more energy-efficient buildings and climate-friendly energy generation.

Munich's Transition Roadmap focuses on collaborating closely to integrate data and analysis tools to, in turn, improve the reliability of H/C planning. The planning aims to inform stakeholders and coordinate activities in the H/C sector, supporting Munich's journey towards climate neutrality. The transformation of district heating is a crucial aspect, involving grid densification, optimization, extension, and a shift towards geothermal energy and other renewable sources. District cooling is also prioritized for reducing power consumption. The integrated neighbourhood approach is employed to realize synergies and coordinate efforts, with neighbourhood concepts and targeted energy counseling campaigns. An energy and renovation agency is being considered for managing implementation at the neighbourhood level. The adaptation of electricity and gas infrastructure is also necessary to accommodate the phase-out of natural gas and the increased electricity demand from heat pumps.

Currently, a new and revised municipal heat plan is being prepared by the Department of Climate and Environment and SWM and will be presented to the City Council in November 2023. At the same time, a transformation plan for district heating (embedded in city-wide H/C-planning) will be sent to a federal agency by SWM to enable funding of investments of both heat grids and heat production or storage installations. After that, there will be a public participation phase on municipal heat planning. Based on this input, a final heat plan and heat transition strategy will be presented to the City Council before mid-2024. At the federal level, an obligatory municipal heat planning law is currently discussed and will likely enter into force in January 2024. Depending on the exact contents of this and related laws (e.g. the building energy law), municipal heat planning will be a more or less binding and a powerful local instrument for the heating transition.

Rotterdam

Rotterdam aims to become climate neutral by 2050 by significantly reducing CO_2 emissions and transitioning away from natural gas. As part of the national Climate Agreement, municipalities are leading the heat transition in the built environment. Rotterdam believes in local management of the transition to ensure residents' understanding and support. The heat transition also presents opportunities to address other challenges, such as climate adaptation, greening, and housing construction, through synergistic solutions. By linking the transition with other district challenges, tailored and cost-effective approaches can be implemented, leading to a better future for all citizens.

Rotterdam's Transition Roadmap, also known as the "WHEN MAP," outlines the plan for Rotterdam to become natural gas-free by 2050. The municipality, along with building owners and heat suppliers, will play an active role in implementing sustainable collective heat

systems as alternatives to natural gas. The WHEN map identifies promising districts for the transition, considering factors such as linking opportunities, feasibility, affordability, and socio-economic benefits. The map differentiates between current district-oriented approaches, districts to start before 2025, districts to start between 2025 and 2030, and districts where the transition will begin after 2030. The goal is to connect 83,000 homes and buildings to clean energy sources by 2030. The map also emphasizes the importance of individual actions, such as energy saving, home insulation, and transitioning to electric cooking. Communication and participation with stakeholders, residents, and property owners are key aspects of the transition process.

The adoption of the ‘WHAT & WHEN MAP’ was a council decision in 2021, outlining “where a collective heat solution is best (WHAT map) & determination of promising areas to start the exit of natural gas before 2030 (WHEN map). The actual decision to start is not taken by the Municipal Council until it is certain that the financial and legal preconditions have been met in time to fully realize this ambition.

Vienna

The City of Vienna is committed to achieving climate neutrality by 2040 through comprehensive strategic climate policies. The Vienna Climate Guide serves as a roadmap towards these goals, outlining the path to a climate-friendly city and identifying key directions for climate protection and adaptation. The guide provides a compact implementation strategy without specifying detailed measures or finalized tools. In line with this guide, the concept "Heating and Cooling Vienna 2040" focuses on transitioning the building sector away from oil and natural gas towards climate-neutral alternatives.

Vienna‘s Transition Roadmap combines elements of the Vienna Climate Guide and the Heating and Cooling 2040 Vienna concept. It highlights the city's climate strategy, provides a detailed outlook on the heating and cooling sector in 2040, outlines key levers in the buildings and energy sectors, and details specific instruments to activate these levers. These include spatial energy planning to expand district heating and utilize renewable energies, a legal framework to phase out fossil fuel heating systems, affordable housing subsidies and financing to make the transition accessible to all residents, communication and guidance to support public participation, and addressing the labour market and skilled workers to meet the demand for retrofitting and renovation. The city aims to create a sustainable and socially just transition while emphasizing the need for coordination with federal-level policies and training programmes.

Both the “Vienna Climate Guide” and “Heating and Cooling Vienna 2040” are politically accepted documents. These documents serve as the basis for the Transition Roadmap presented within the Decarb City Pipes project. The energy planning department (MA20) was leading the process of the development of those documents with a huge number of experts from inside and outside the administration. The new “Phase Out Gas” programme started in 2022 and is planned be the vehicle for implementing the decarbonisation of heating and cooling.

Winterthur

In 2013, Winterthur City Council adopted the Municipal Energy Plan Winterthur (Energy Plan 2011), which was later supplemented by the Energy and Climate Strategy 2050 due to tightened climate targets at national, cantonal, and municipal levels. Stadtwerk Winterthur, the utility, has since implemented additional district heating networks, increased the connection density in the district heating area, and has announced the discontinuation of gas supply to the district of Gotzenwil by the end of 2026. With significantly changed circumstances in climate targets on the national, cantonal and municipal level, the Energy Plan 2013 and the roadmap had to be thoroughly revised and updated to align with the new goals and conditions. As is currently stands, Winterthur adopted a net zero target by 2040 in 2021, and the cantonal energy law with a wide-ranging prohibition of fossil fuel boilers entered into force in 2022. Winterthur's new Energy Plan[3], paving the road to implementation of these new framework conditions, was approved by city parliament in late 2022 and came into force in early 2023, and is the primary basis for the present Transition Roadmap.

To achieve Winterthur's energy and climate goals, several measures are planned. These include an ongoing engineering study to connect thermal networks and maintain flexibility, organization and resource building with support from Stadtwerk Winterthur and the city's departments, information campaigns and a building-specific energy cadastre plan, implementation and impact controls to monitor progress and assess the effects of measures, and transitional solutions for property owners replacing oil and gas heating systems. These measures aim to facilitate the expansion of thermal networks, provide consistent information to stakeholders, ensure effective implementation, and support a smooth transition to climate-neutral heating systems.

[3] https://stadt.winterthur.ch/gemeinde/verwaltung/stadtkanzlei/kommunikation-stadt-winterthur/medienmitteilungen-stadt-winterthur/revision-des-energieplans-fuer-die-waermeversorgung-1/download/20220630-kommunaler-energieplan-winterthur.pdf

Cross-City Comparison

Current Heating and Cooling in Cities

A first comparison between the cities can be found in the table below.

TABLE 2: COMPARISON BETWEEN CITIES: INHABITANTS AND CURRENT ENERGY MIX IN H/C MARKET (SPACE HEATING AND DOMESTIC HOT WATER)

	Bilbao	Dublin	Munich	Rotterdam	Vienna	Winterthur
Inhabitants	*350,000*	*1,263,000*	*1,594,000*	*650,000*	*1,982,000*	*110,000*
Gas Boilers	80%	72%	53%	66%	41%	
District Heating		1%	35%	29%	41%	
Oil Boilers	5%	10%	9%		5%	
Electric (Direct)	7%	15%	1%		9%	
Electric (HP)	8%		1%	5%	1%	
Biomass Boilers		2%	1%		3%	
Final Energy Demand for Heating (GWh)	852	9,980	8,400	4,583	13,000	
Final Energy Demand for Cooling (GWh)	136	0	300	390	500	

As can be seen from the table, the cities differ in size and in the way heating and cooling is provided but all still use significant shares of fossil fuels.

The project cities exhibit diverse energy landscapes and heating and cooling systems. Bilbao's relatively smaller population leads to a heavy reliance on Gas Boilers (80%) for heating. Dublin's larger size prompts a mix of energy sources, with Gas Boilers (72%), Oil Boilers (10%), and a notable combined percentage of Electric (Direct + HP - Heat Pumps) (15%). Munich, with a considerable population, stands out for its substantial adoption of District Heating (35%) alongside Gas Boilers (53%). Rotterdam, similar in population size to Bilbao, mainly relies on Gas Boilers (66%) and District Heating (29%), using Electric (HP - Heat Pumps) (5%) for cooling. Vienna, the largest city among them, demonstrates a balanced approach, using both Gas Boilers (41%) and District Heating (41%) for heating. These variations reflect the impact of population size, resource availability, and regional policies, showcasing the importance of tailored energy solutions for each city's unique needs.

Climate Neutrality Goals & Governance Settings

As part of the Decarb City Pipes project, each city has created a heating and cooling outlook and plan, providing a future picture of the city in which the heating and cooling sector is

decarbonised. In doing so, the cities are working toward "carbon neutrality," "climate neutrality", "zero emissions," or "natural gas-free heating." Although all cities define their goals in different terms, they are all working to decarbonise the heating system for their building stock. In doing so, they are clearly moving away from fossil fuels for heating. The H/C plans represent a vision of how this decarbonisation can be realized. The table below summarises each of the cities' climate goals and the year in which they are expected to be reached. It also includes key targets that must be achieved to meet overarching climate ambitions.

TABLE 3: PROJECT CITIES' CLIMATE GOALS

City	Goal	End year	Other values & heat transition goals
Bilbao	Carbon neutrality	2050	2030: reduction of 55% GHG emission. First analysis of potential decarbonisation strategies and renewable thermal grids Goal for building stock is translated to zero fossil fuel use in 2050.
Dublin	Net zero	2050	National Climate Action Plan target: 2.7TWh of all residential and commercial heating to be supplied via district heating by 2030 and 0.8TWh by 2025. 400,000 heat pumps to be installed in existing dwellings, and 280,000 heat pumps to be installed in new dwelling by 2030. Up to 0.7 TWh of heating to be supplied by renewable gas by 2030.
Munich	Climate neutral	2035	Climate-neutrality for the city administration by 2030; recommended climate-neutrality for municipal companies by 2030.
Rotterdam	Natural gas free heating	2050	2030: Rotterdam will reduce CO_2 emissions by 55% compared to 1990 and will be climate neutral by 2050. By 2030, 85,000 homes will be removed from the national gas grid and by 2050, no homes will be heated by natural gas.
Vienna	Carbon neutrality	2040	Phase-out of fossil fuels for heating, cooling, and hot water production by 2040; reducing GHG emissions by 55% until 2030; reducing final energy consumption for heating, cooling and hot water by 20% until 2030 and by 30% until 2040 (all targets per capita and compared to 2005)
Winterthur	Net zero	2040	Various parts of the gas network will be decommissioned. Gas is used for peak supply. An interim target of 1.0 tCO2eq. is set for 2033, by which fossil gas will largely be phased out while the proportion of green gas will increase.

Despites these differences in the delivery year, all cities aim to fully decarbonise their heating and cooling. It is clear that in order to so, further action is required. The transition roadmaps set out these actions for each city. In addition, they also discuss who will lead these actions and when they should be delivered.

To give an overview of the current situation, Table 4 below highlights how the policy and legal framework in force for each city addresses fossil fuel heating systems.

TABLE 4: OVERVIEW OF EXISTING POLICIES REGARDING THE PROHIBITION OF OIL, COAL AND GAS FOR HEATING AND COOLING (SOURCE: D6.1)

Country / City	Prohibition of Oil & Coal for Heating		Prohibition of Natural Gas for Heating		Comment
	New Buildings	Existing Buildings	New Buildings	Existing Buildings	
Spain / Bilbao	Yes	Yes, for coal but not for oil (cannot be replaced)	No	No	Commitment to remove oil/coal heaters by 2030
Ireland / Dublin	No	No	No	No	nZEB standards for new buildings make fossil fuel heating difficult. A ban is being discussed for new and renovated buildings.
The Netherlands / Rotterdam	No[4]	No[4]	Yes	No	New legislation in development
Austria / Vienna	Yes	No	in parts of Vienna	No	Renewable Heat Act (Erneuerbare-Wärme-Gesetz) on federal level in development.
Germany / Munich	Yes	No	No	No	Federal government plans that new heating systems installed are to be operated with a share of at least 65% of renewable energies.
Canton of Zurich / Winterthur	Yes	Yes (cannot be replaced)	Yes	Yes (cannot be replaced)	New cantonal energy law in force since 2022, prohibiting the use and the replacement of fossil fuel boilers.

[4] Oil & coal only play a very minor role in heating in the Netherlands.

Heating and Cooling in the Future

In a first step of the project, all six cities – Bilbao, Dublin, Winterthur, Rotterdam, Vienna, and Munich – each developed their own H/C Outlooks. These H/C Outlooks included a quantitative breakdown of future energy supply and demand for heating and cooling systems. It required each city to reach an internal consensus on their desired goals and direction for their heating and cooling systems.

By considering current and future energy demand and supply, these cities made informed decisions regarding specific energy carriers to prioritize within their H/C systems. For that purpose, the cities conducted a thorough assessment of their current energy sources and infrastructure. Moreover, they took into account future availability considerations, such as the evolution of demand and heat source potentials,

While the H/C Outlook of each city presented at the start of the project is still accurate in orders of magnitude, Table 5 shows an updated outlook to the future H/C energy mix, drawing from the cities' most recent data.

TABLE 5: OVERVIEW OF CITIES' H/C OUTLOOKS IN TERMS OF FUTURE ENERGY MIX (SPACE HEATING AND DOMESTIC HOT WATER)

	Bilbao (2050)	Dublin (2050)	Munich (2035)	Rotterdam (2050)	Vienna (2040)	Winterthur (2040)
Gas Boilers	0%	0%	32%	4%	0%	
District Heating	30%	87%	53%	85%	56-70%	
Oil Boilers	0%	0%	1%	0%	0%	
Coal Boilers	0%	0%	0%	0%	0%	
Electric (direct)	10%	0%	1%	0%	0%	
Electric (HP)	60%	13%	11%	11%	28-42%	
Biomass Boilers	0%	0%	3%	0%	2%	
Estimated refurbishment rate (%)	2%	3-4%	1.7%	2.4-3%	Avg.: 2% (increasing from 1.2 to. 2.5%)	
Final Energy Demand for Heating (GWh)	758	9,190	5,600	4,773	10,000	
Final Energy Demand for Cooling (GWh)	136	1000	800	390	1,000	

In the future, the cities of Bilbao, Dublin, Munich, Rotterdam, and Vienna are projected to undergo significant shifts in their energy usage and heating and cooling systems. Bilbao is expected to completely eliminate gas boilers, showcasing a clear commitment to moving away from fossil fuel-based heating. Instead, the city is predicted to adopt electric heat pumps (60%) as the primary source for heating, indicating a move towards more energy-efficient and sustainable cooling solutions. Dublin's energy landscape is forecasted to be dominated by district heating (87%), reflecting the city's emphasis on centralized and environmentally friendly heating systems. In Munich, district heating (53%) will also continue to play a significant role in the future, supplemented by electric heat pumps (11%) and

biomass boilers (3%) to enhance the sustainability of its heating infrastructure. Rotterdam is anticipated to undergo a remarkable transformation, with district heating expected to meet a substantial portion (85%) of its heating demand, signifying a major shift towards cleaner and centralized heating solutions. In contrast, Vienna is projected to adopt a balanced approach with a substantial share of district heating (56-70%) for both heating and cooling needs in particular in dense urban areas, complemented by electric heat pumps (28-42%) to further promote energy efficiency. The cities are also estimated to undertake refurbishment rates ranging from 1.2% to 3-4% on average, indicating their collective commitment to modernize and improve energy efficiency in their heating infrastructures. These projected changes illustrate the cities' determination to address environmental challenges and embrace more sustainable, cleaner, and energy-efficient solutions for the future.

Cooling

All cities considered cooling to a certain degree, it is, however, not yet integrated into the H/C plans. The cities aim to make cooling part of the updated versions of the H/C plans, since a city's cooling demand could influence the preferred heat option.

Most cities already analysed their cooling demand (density), e.g. Vienna looked at expansion of cooling networks (as separate system) and Bilbao used the heating/cooling ratio to decide in which places the use of heat pumps would be preferred. Rotterdam analysed its cooling demand and a made plan on how to deal with it. Munich integrated cooling for non-residential buildings in the H/C plan, outlining potential district cooling. Winterthur analysed its cooling demand by regarding the data about industry affiliation from company statistics. Areas with high cooling[5] demand are identified in the H/C plan. These are to be considered in future district heating planning.

Heat demand

The estimated energy use for heating is known in all cities. The cities also calculated potential heat demand reduction in time. Most cities have information regarding the type of buildings and calculated potential reductions based on assumptions how the building stock can be retrofitted. The retrofitting rate in most cities currently is about 1% per year. The cities' ambitions, however, are higher.

All cities use standard building data to calculate the heat demand and potential reductions (retrofit). The different types of buildings (e.g. building year, ground bound / apartment flats and ownership) are taken into account. Dublin incorporated behavioural aspects in the energy demand calculations. It was found that the rebound effect (the percentage of theoretical savings compared to the actual savings) was 26.7% for homeowners and 41.3% for tenants. This difference between theoretical and actual energy consumption (also called performance gap) is caused by behavioural aspects. For example, rooms in well insulated homes are heated more often than in badly insulated homes. Bilbao warns in their H/C plan against overestimating the potential impact of (retrofit) measures. Old buildings often have lower energy consumption than calculated, not only due to the behavioural aspects mentioned, but also because retrofitting measures have taken place in many of these buildings but have not yet been included in the calculations. The cities of Vienna and Dublin

[5] A detailed paragraph on cooling can be found in the H/C Guideline (D3.2):

expect significant population growth over the next decade(s), which will lead to an increase in heating demand. However, this will be limited compared to the existing building stock, as most buildings are expected to be built to near zero emission standards.

Energy supply

For the decarbonisation of the heating and cooling demand, fossil-free energy sources are needed. All cities still use more than 50% of fossil fuels in their heating system, especially natural gas. Natural gas is used for the heating of the building stock, either directly via gas boilers in the buildings or via CHP and peak and backup systems to produce heat for the existing district heating systems.

To meet the cities goals, the energy supply for heating needs to become fossil-free. Still, for most cities in the coming years, gas is often seen as a means to meet the heat demand and specifically the peak and back-up demand in district heating systems. In time, this natural gas either needs to be exchanged to alternative energy carriers or needs to become green (either H_2 or biogas). However, all of the cities assume that there is not going to be enough green gas to replace natural gas in full and that this gas should be used for sectors where alternatives do not already exist (e.g. electricity generation, heavy transport and aviation, some high temperature heating). So the bigger part of current gas-based heating systems needs to be replaced by heating systems that can use other heat sources[6]. This is either with (individual) heat pumps or district heating networks. This transformation of heating system enables the use of a wide range of (local) energy sources to heat the building stock.

Munich, Rotterdam, Vienna and Winterthur already have a district heating system in place, Dublin has a small number of DH networks and Bilbao has no DH (yet). Most of the cities still use natural gas as the main energy source for their heating systems. However, not all cities are completely dependent on it, e.g. Rotterdam, Vienna, Munich, Winterthur also use heat from waste incinerators. Rotterdam and Vienna also use waste heat from the industry (first connections have already been built, e.g. with a refinery; more are planned in the future) and Dublin is using waste heat from data centres.

Heat sources to be harnessed

There are many different heat sources for district heating, the most important ones are summarized in the table below and a more extensive list can be seen in the H/C Plans[7].

TABLE 6: HEAT SOURCES CONSIDERED FOR USE IN DISTRICT HEATING SYSTEMS

Heat source for district heating systems	Remarks
Geothermal heat (deep)	All cities except Bilbao looked at the potential of geothermal heat.
Industrial waste heat	Cities with industrial complexes nearby, like Rotterdam, use or are planning to use this kind of heat. The future availability of waste (or recoverable) heat due to decarbonisation of the industry itself is, however, a point of attention.

[6] This will be distric heating using geothermal heat, aquathermal heat and/or waste heat, heatpumps using electricity or a combination of district heating and heatpump using both the heat sources as well as electricity.

[7] https://decarbcitypipes2050.eu/wp-content/uploads/2023/06/D3.3-HC-plans-and-cross-city-synthesis-FIN.pdf

	How much heat and at what temperature will be available in the future, needs to be analysed.
Waste incinerator	Most cities use or are planning to use heat from waste incinerators (Dublin, Munich, Rotterdam, Vienna, Winterthur). Circular economy aspects (no-waste strategy) are expected, however, to influence the future amount of available heat. How fast this no-waste future will unfold and what impact it will have on waste-to-energy plants is yet unknown.
Lower temperature waste heat (e.g. heat from data centre, local industry)	Especially heat from data centres are being considered. Not all cities have this potential, though. A lot of low temperature sources are also available in urban fabric areas (e.g. bakeries, supermarkets) – altogether the have a high potential for low-temperature networks or for direct use in neighbouring buildings.
Aqua thermal energy (e.g. energy from surface water, waste water, ground water)	This type of heat needs to be upgraded by heat pumps, either by individual or large-scale heat pumps. All cities are looking at different types of aqua-thermal heat, but availability is most often low compared to heat demand.
Electricity	Cities will not be able to produce enough electricity within the city (excluding offshore wind) to fully meet the electricity demand. Cities are primarily looking for solar solutions (rooftop installations) within the built environment and win-win solutions, using PV elements for shading public spaces or combining green elements with PV installations on buildings. The rest of the electricity generation will come from wind (both onshore and offshore) and hydro power, mostly generated outside of cities. Electricity can be used to generate heat through heat pumps (both, on a large scale as part of district heating, as well as through individual heat pumps to heat individual buildings).
Green gas (H_2, biogas)	All cities expect to have a limited amount of green hydrogen[8] and biogas available by 2030. This high-value energy carrier and source is preferably used for industry (requiring high temperatures) or serving as feedstock, heavy transport and/or balancing the energy system. This balancing is needed for both, the electricity as well as district heating systems. Munich as well as Vienna, for example, are examining whether there is enough green gas to meet current peaks in heating and electricity demand as well as for back up purposes in these systems.

[8] H_2 is, unlike biogas not an energy source but an energy carrier, it is made in an electrolyser using (green) energy sources.

Key Actions from the Transition Roadmaps

Throughout each of the Transition Roadmaps, common goals and approaches for transitioning to more sustainable heating and cooling systems are evident. All cities recognize the need to phase down the use of fossil gas and ban fossil fuel boilers, emphasizing the importance of reducing reliance on fossil fuels. Additionally, they aim to densify, extend, and decarbonize existing district heating infrastructure, promoting efficiency and environmental performance. Introducing zoning regulations for district heating and cooling is seen as crucial, encouraging expansion and adoption of these systems. Making high granularity utility data available for energy planning purposes is also a shared priority, enabling informed decision-making and efficient energy management. While these common approaches provide a foundation, each city also has specific strategies tailored to their unique circumstances and goals.

Bilbao, Dublin, Munich, Rotterdam, Vienna and Winterthur identified in their city transition roadmaps the following key actions:

- Legal basis for the phase-down of fossil gas (including ban of fossil fuel boilers): **All cities**[9] have recognized the need to establish a legal framework to phase down the use of fossil gas and ban fossil fuel boilers. These actions are part of their future plans for transitioning to more sustainable heating and cooling systems.
- Densify, extend, and decarbonize current district heating: Cities with existing district heating infrastructure have plans to actively engage in densifying, extending, and decarbonizing their existing district heating systems. These planned actions aim to improve the efficiency and environmental performance of the H/C infrastructure.
- Introduce zoning for district heating and cooling (DHC): **All cities**[10] have recognized the importance of introducing zoning regulations for DHC. The plan is to establish zones where certain buildings are required to futureproof for connection and mandate connection to DH networks, fostering the expansion and adoption of district heating systems.
- Make high granularity utility data available for energy planning purposes: **All cities** recognize the importance making detailed utility data available for energy planning purposes. This action will enable informed decision-making and efficient energy management.
- Update legal act (MUD Act) to allow longer heat contracts in multi-tenant buildings: **Dublin**[11] intends to update the MUD Act to enable residents in multi-tenant buildings

[9] Winterthur law example where a shut-off date for gas to flow through the gas network has been set for 2032 and gas boilers have been banned as of 2020 - https://www.zh.ch/de/politik-staat/gesetze-beschluesse/gesetzessammlung/zhlex-ls/erlass-730_1-1983_06_19-1986_07_01-118.html?search=energiegesetz

[10] Vienna legally binding energy zoning plans

[11] The limit on the duration of contract is a barrier to development of DHC as revenues from the large upfront capital investment.

to sign longer heat contracts. This planned action aims to provide stability and encourage long-term sustainable heating solutions.

- Create a dedicated fund for the delivery of DHC networks: **Dublin** plans to establish a dedicated fund to support the delivery of DHC networks. This planned financial support aims to facilitate the development and expansion of district heating infrastructure in the city.
- Foster pilot programs for immediate actions: **Vienna** intends to foster pilot programmes, such as the "100 buildings and projects phasing out of gas," as part of their plans to accelerate immediate actions towards decarbonization.
- Focus on solar energy generation within the city: **Vienna** has planned a specific emphasis on solar energy generation within the city, highlighting their commitment to harnessing renewable energy sources for H/C systems.
- Enhance the use of (shallow) geothermal energy: **Vienna** has plans to actively enhance the use of (shallow) geothermal energy, showcasing their intentions to tap into geothermal potential for heating and cooling purposes.
- Facilitate, standardize, and accelerate planning and permitting of district heating decarbonization based on deep-geothermal energy: **Munich** has future plans to take proactive steps to facilitate and streamline the planning and permitting processes for decarbonizing district heating based on deep-geothermal energy.
- Scale integrated neighbourhood concepts and provide targeted energy counselling at the neighbourhood level: **Munich** has future plans to focus on scaling integrated neighbourhood concepts and offering targeted energy counselling, highlighting the importance of community-level approaches to the H/C transition.
- Realize local heat grids based on near-surface geothermal energy and other renewable energy sources: **Munich** is actively working towards plans to realize local heat grids based on near-surface geothermal energy and other renewable energy sources. These planned actions will contribute to their transition to more sustainable heating and cooling systems.

What's next for DCP 2050?

Decarb City Pipes 2050 is a pioneering project that brings together cities across Europe in developing actionable plans for decarbonizing heating and cooling systems in buildings by 2050. The project recognizes the urgency of starting the planning process given the long life cycles of grid infrastructures which brings about challenges in terms of capacity, skills, and legal empowerment to undertake this transition effectively. Through the development of Transition Roadmaps, the Decarb City Pipes 2050 project has addressed these issues by fostering collaboration, knowledge sharing, and capacity-building among cities. The goal is to advocate for necessary changes in framework conditions to support successful decarbonization efforts in the pilot cities, and ultimately, for cities all over Europe.

Looking to learn more about the individual journey each city took as part of the process? The Transition Roadmap documents for each city are included as appendices below and Table 7 contains the main points of contact.

TABLE 7: MAIN POINTS OF CONTACT FOR TRANSITION ROADMAPS

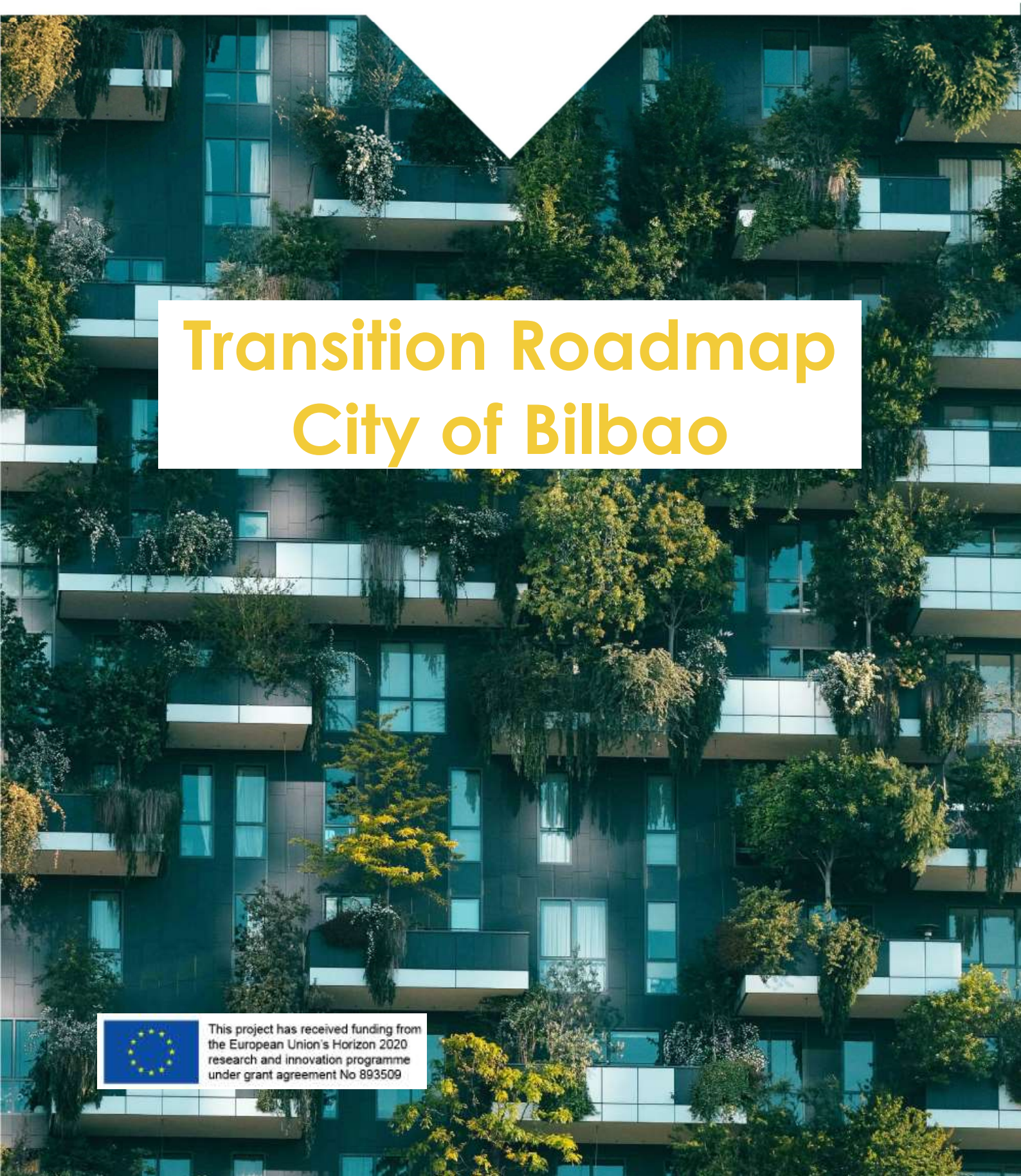
City	Contact
Bilbao	Jon Gonzalez Mancisidor, International Projects Technician, Bilbao City Council Email: j.gonzalez@bilbao.eus
Dublin	John O'Shea, Heat & Electricity Lead (Codema) Email: john.oshea@codema.ie
Munich	Tilman Rave, City of Munich, Department of Climate and Environment Email: tilmann.rave@muenchen.de
Rotterdam	Marie-Emilie Ingen-Housz, Process Manager Energy Transition, City of Rotterdam Email: mfp.ingenhousz@rotterdam.nl
Vienna	Herbert Hemis, Energy Zoning & Energy Data Expert (City of Vienna) Email: Herbert.hemis@wien.gv.at
Winterthur	Energy Department, City of Winterthur Email: energiefachstelle@win.ch

To learn more about the other outputs from this project, please visit the project website (https://decarbcitypipes2050.eu/).

Appendix:
Cities' Transition Roadmaps

DECARB CITY PIPES 2050

Transition Roadmap City of Bilbao



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Transition Roadmap of Bilbao

Introduction

The city of Bilbao is a clear example of urban regeneration. Over the last 40 years, it has evolved from a totally industrial city with high levels of pollution to a city based on advanced services, technology and knowledge. Indeed, since the city started the restructuring of its industrial network by moving the harbour outside municipal limits, building a subway network, treating the sea inlet, and rebuilding a tram line, Bilbao has positioned itself at the forefront of the modernisation pathway.

As part of this path, the city also integrates sustainability and energy efficiency criteria in this process. Bilbao is clearly committed to meet climate neutrality by 2050, and the Bilbao Environmental Strategy 2050 dissects this ambitious plan into a compendium of strategic lines in order to handle the mitigation of CO_2 emissions and the adaptation to climate change.

Aligned with this environmental strategy, the city is subscribed to the Covenant of Mayors network. As part of that cooperation, Bilbao published in 2012 an Action Plan for Sustainable Energy (SEAP) which committed to reduce at least 20% of CO_2 emissions by 2020 with regard to 2005 levels. This milestone was surpassed by a wide margin and the city is strongly determined to develop a Sustainable Energy and Climate Action Plan 2030 (SECAP), which aims at a 55% GHG reduction.

The SECAP is still under development, and it will also underline the heating decarbonisation issue as a key factor for the city's transition. Cornerstone measures to be included are the reduction of energy use, promotion of building retrofitting, integration of renewable energies and extensive district heating networks analysis. In this sense, Bilbao has benefited from participating in Decarb City Pipes 2050 – being the first project dealing with decarbonising the heating and cooling sector for the municipality – to build up a strategic Heating and Cooling (H/C) 2050 vision and a data-extensive spatial mapping for the city's H/C Plan.

Bilbao's big urban transformation during the last decades was performed thanks to a very efficient and autonomous urban governance model through a public-private collaboration model which involved local and national administrations as well as private partners. This background and valuable experience can now be applied to carry out the heating transition. Nowadays, the city has almost complete autonomy over urban planning which presents as a clear advantage.

Bilbao's Transition Roadmap comprises essential information of the heating and cooling sector, identifies barriers and strengths of the city and elaborates on the most relevant instruments to accomplish an emission-free heating and cooling sector.

Bilbao's Status Quo and Climate Neutrality Target

GHG Emissions and Energy Consumption

Figure 7 outlines the evolution of annual CO_2 emissions between 2005 and 2018 in Bilbao. It is the most recent period for which representative data is available. During this time, emissions have been reduced by 38%, which is significantly higher than the original target. The municipality intends to continue this path and has committed itself to a 55% reduction by 2030 in the SECAP. These goals call for a series of measures and interventions in key sectors: transport, services, industry, waste and residential.

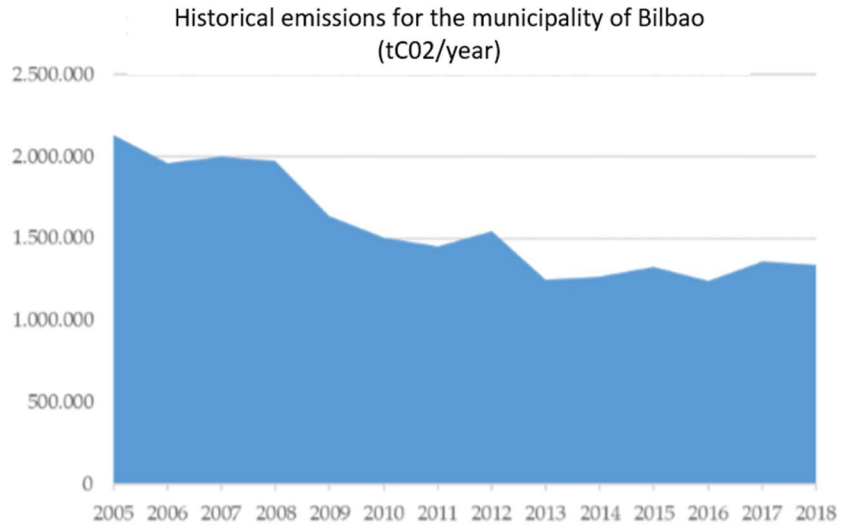

FIGURE 7: HISTORICAL EMISSIONS OF THE MUNICIPALITY OF BILBAO (tCO_2/YEAR)

Figure 8 shows that the transport sector is the largest contributor to GHG emissions, while the residential sector has recorded the highest GHG savings over the years. This is primarily due to the increasing share of renewables in the electricity grids, and to a lesser extent to the replacement of oil-fired boilers for other variants of heating systems.

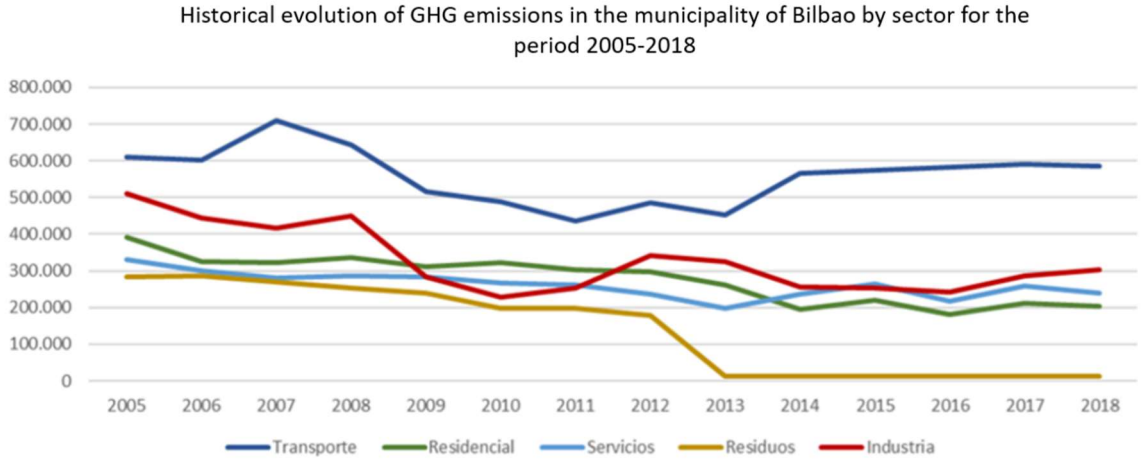

FIGURE 8: HISTORICAL EVOLUTION OF GHG EMISSIONS IN THE MUNICIPALITY OF BILBAO BY SECTOR FOR THE PERIOD 2005-2018

The evolution of the energy consumption over the years is a reliable indicator to analyse whether the municipality is reaching its targets and whether it is really becoming more energy-efficient. Figure 9 shows the total energy consumption by sector. The transport sector is the main consumer, with industry only responsible for a very small part, and the residential and service sectors are responsible for similar shares.

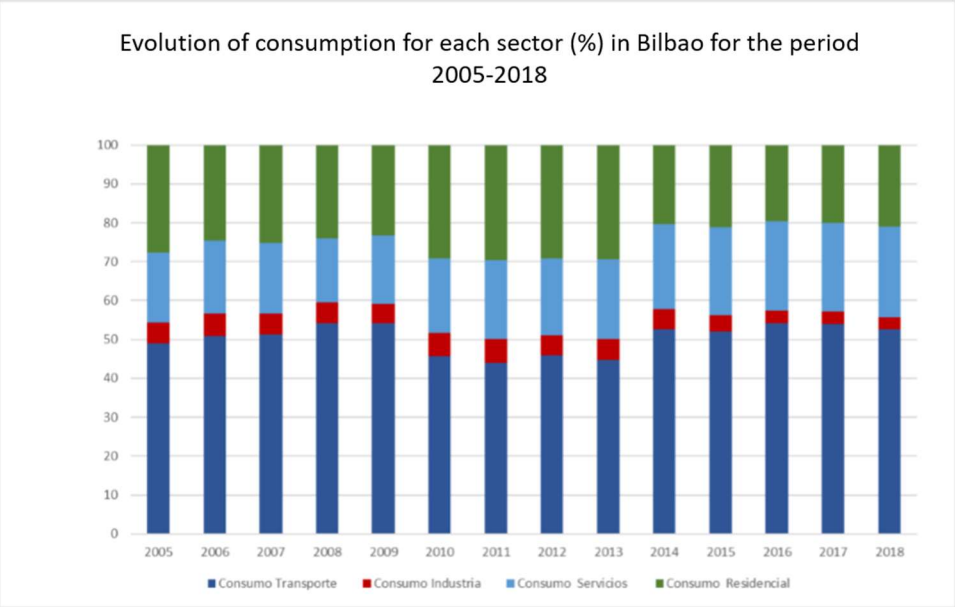

FIGURE 9: EVOLUTION OF CONSUMPTION FOR EACH SECTOR (%) IN BILBAO FOR THE PERIOD 2005-2018

Figure 10 displays the annual consumption in kWh for the service and residential sector for the whole municipality, differentiated by type of thermal or electrical energy (*there is a mismatch since heat pumps, for instance, are not considered for thermal energy).* Overall, there is a general reduction of 12% of total energy, but there is also a slight upturn in thermal energy during last years, mainly due to an increase of activities in the service sector.

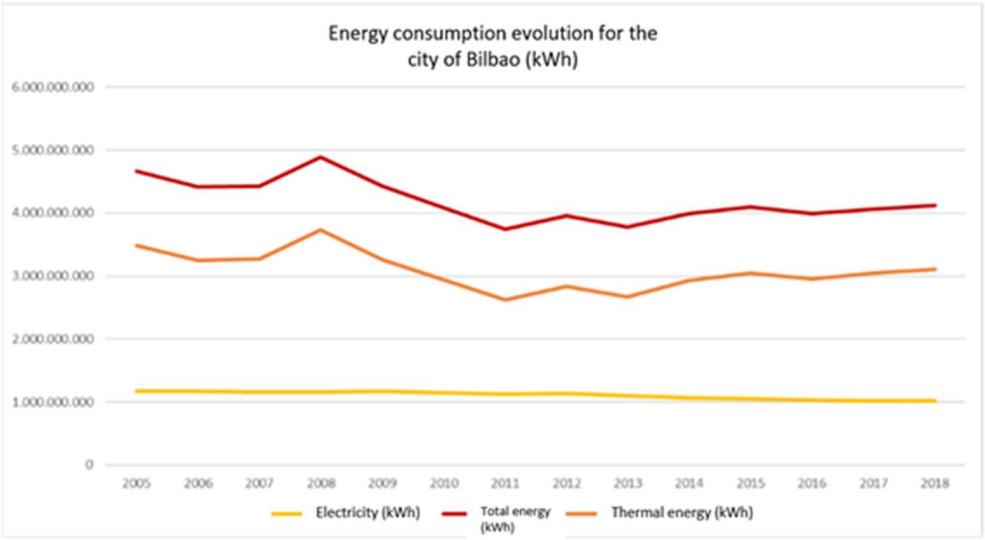

FIGURE 10: ENERGY CONSUMPTION EVOLUTION FOR THE CITY OF BILBAO (KWH)

Building sector

When analysing the building sector, it represented almost a 50% of the total energy consumption in the city in 2018 and was responsible for approximately 33% of CO_2

emissions. Electricity for lighting and auxiliary equipment, and natural gas for heating are the main energy carriers. Due to the mild climatic conditions in Bilbao, there are not very high heating demands as compared to other northern European countries. Regional and national strategies have generally prioritized the decarbonisation of the electricity production, and heating supply has not been studied in detail. Despite that, Decarb City Pipes 2050 states the relevance of cutting down fossil fuels in the thermal sector by a step-by-step heat roadmap.

Natural gas is by a wide margin – around 80% – the most used energy source for heating, cooling and hot sanitary water supply in Bilbao. More than half of that amount corresponds to heating while cooling has a very low impact. Figure 11 shows the distribution of different equipment and types of heating in the residential sector. Remarkable is the low penetration of individual heat pumps (below 1%), the considerable direct use of electricity (15%) and the extensive use of individual gas boilers (50%), which are the most common heating infrastructures in the city.

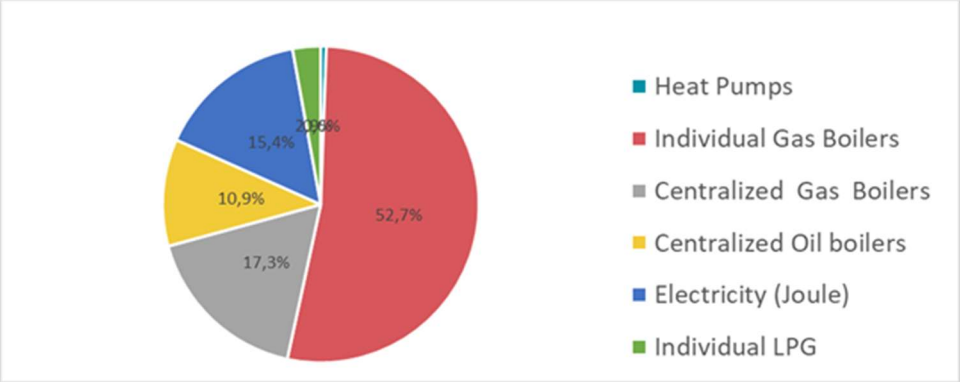

FIGURE 11: DISTRIBUTION OF DIFFERENT EQUIPMENT AND TYPES OF HEATING IN THE RESIDENTIAL SECTOR

Figure 12 depicts the distribution of heating systems per use of building in the non-residential sector. For tertiary commercial buildings, natural gas boilers are still the most common systems but there is a noticeable 30% of use of heat pumps.

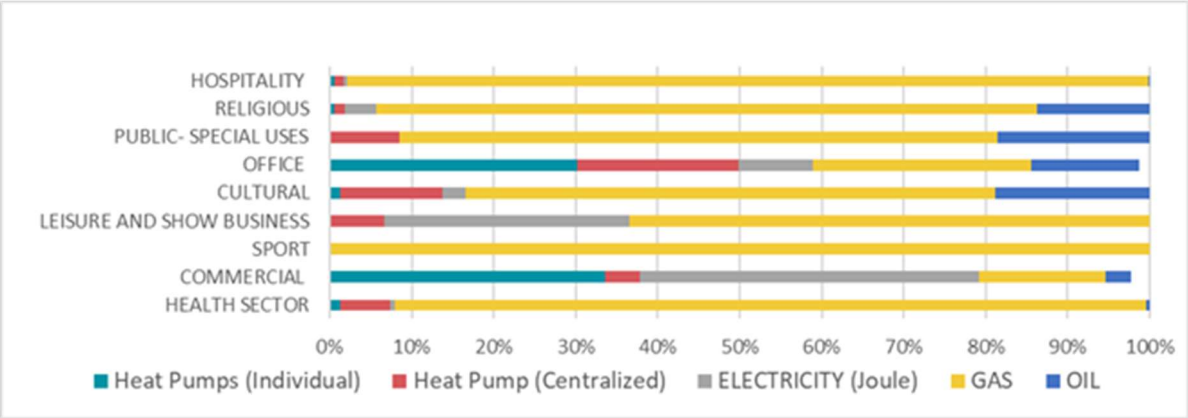

FIGURE 12: ENERGY MIX IN DIFFERENT BUILDING TYPES

The building sector in Bilbao is confronted with the following circumstances:

Promotion of refurbishment rate: Hundreds of buildings in Bilbao are even older than 100 years and their envelopes do not meet high energy efficiency criteria. Their renovation is a priority task for the city, and very efficient or 'passive buildings' are to be reached in those areas where district heating networks are unlikely to be developed. The current

refurbishment ratio is rather low – around 0,5% -, and it needs to grow exponentially next years to reach the agreed objectives for decarbonisation.

Energy efficiency: An improvement of overall energy performance of the building stock, including decarbonisation of the heating system and new requirements for the building envelope, are required by different standards and regulations. The national Technical Building Code prescribes that a minimum annual contribution of renewable energy must cover the domestic hot water (DHW) needs of buildings with at least 100l/d demand. (60% RE when the DHW demand is lower than 5000l/d and 70% if it is higher). This directive is applicable to residential, private and public buildings. Solar power, biomass boilers or heat pumps are the most suiting renewable source systems in this regard. In addition, buildings with more than 1000m^2 of constructed area are forced to install PV energy to produce electricity.

Exemplarity of public administrations: the most ambitious goals must be set for the public buildings. A better insulation of the facade of buildings as well as behavioural changes in habits for users are key factors for the reduction of energy consumption. As an example, the national government has set a directive that limits the interior temperature of heated and cooled spaces to 19 degrees in winter and 27 degrees in summer. That measure is also applicable for tertiary buildings.

In addition, a progressive replacement of heating systems towards renewable energies must be considered. The Basque Sustainability Law enacts the inclusion of renewable energies, stipulating that public administration buildings must cover their electricity and heat demand at least by 32% through on-site renewable energy generation. For example, when implementing a district heating network, and particularly if the investment comes from a private party, reliable initial potential consumers such as public buildings with high energy demands allow for planning certainty and reduces investment risks.

Citizenship engagement and affordable financial schemes: Whatever the alternative to fossil fuels needs an adequate sustainable business model to thrive. Social sustainability and affordability are key parameters in the energy transition. Bilbao tackles an extra-challenge: most of the buildings are privately owned by multifamily housing and every decision for the buildings must be endorsed by 2/3 of the co-owners. Only 4.000 buildings are municipally-owned, which is a 1/85 ratio. Additionally, Bilbao has a relatively elderly population which hampers the acceptance of changes, such as for heating systems. The initiation of public-private collaboration projects is considered fundamental.

There is a need of launching incentives or subsidies promoting energy efficiency measures in the private sector. The National Institute for Diversification and Saving of Energy, for example, has established an annually updated funding programme (implemented in the Basque Country through the Basque Energy Agency) to support energy rehabilitation of existing buildings, covering i.e. thermal renovation, energy efficiency improvements of heating systems (e.g. the replacement of conventional energy for solar thermal) or lighting installations. This funding also covers the switch from a fossil-based heating system or switch to a renewable heating system based on e.g. biomass, aerothermal or geothermal energy.

Legal framework: No direct measures with regard to total decarbonisation of the thermal sector at regional and national level are in force currently and, unfortunately, none are expected to enter into force in the short term. There is no ban or limitation on gas or on gas heaters planned and there are still no plans or discussions about the decommissioning of gas infrastructure. However, coal heating systems are indeed forbidden to be installed in new and refurbished buildings since 2007, while oil heaters are not prohibited at national level, but the Basque Sustainability Law of 2019 has taken the strong commitment to abandon them by 2030. Existing oil boilers, which are mostly old and inefficient, are generally being replaced by gas boilers.

Gas network and supply operation and management: Unlike other European cities, thermal energy suppliers and natural gas network operators in the city of Bilbao are private, which creates a challenge for the implementation of a district heating or other individual solutions. Additionally, the gas network was constructed in Bilbao only around 35-40 years ago (being not very old) and meant a high investment for the municipality, making it difficult to think about substantial remodelling and decommissioning in the short-term. The ideal strategy consists of engaging existing gas network companies in the deployment of big-scale renewable heating systems, since they already have a high knowledge and expertise on the exploitation of energy sources.

Renewable energies

Waste heat from companies, data centres etc. are not considered a major energy source in Bilbao, as there are no large industries or computing centres within the municipality. Biomass is also rejected due to the emission of particles and logistics issues. Individual solutions (e.g. air source heat pumps) and centralized DH networks based on geothermal energy or hydrothermal exchange are considered the most favourable solutions for decarbonisation.

Heat pumps

The deployment of individual air-source heat pumps (HP) may be the least intrusive pathway for the administration, as existing gas boilers can be progressively replaced by HPs once their life cycle finishes. In certain areas of the city, however, heat pump installation is currently hampered through local heritage protection laws, such as in the old town of Bilbao (e.g. attachment to the roof prohibited). The high upfront investment costs, and generally the lack of knowledge, expertise and experience of installing heat pumps to substitute centralized boilers in multifamily buildings are also an obstacle. New buildings are likely to be equipped with HP, but it is not very common in already existing buildings yet.

District Heating (DH) systems

Although they currently are the more efficient system, there are no laws in place that favour DH over individual heating systems. Only the Basque Sustainability Law mentions it in a specific article for local administrations, requiring them to foster studies for centralized energy systems in order to improve energy efficiency of the existing building stock. For new developments, it requires them to consider centralized energy systems for energy supply, and the use of renewable energies.

The only existing operative DH in Bilbao is a small network that supplies heating and cooling to the hospital buildings of Basurto and is based on biomass and natural gas. A DH pilot based on a geoexchange low-temperature network is being implemented in the still non-urban developed area of Zorrozaurre, and it is planned that residential, tertiary and industrial buildings will be able to connect to the grid.

Stakeholders: Besides the municipality, there are other crucial actors for the energy transition: the Basque Energy Agency is a very important entity that has led the decarbonisation of the region over the last 40 years. Nevertheless, the decommissioning of the natural gas network is currently not a priority since old oil boilers are still being replaced by natural gas boilers and subsidies are being granted for that. Also, representatives from the industry such as Tecnalia are important in this process through their knowledge and experience in the sector. Indeed, the Basque Country has a very powerful auxiliary industry in the energy and electricity sector, including companies with great expertise such as Iberdrola and Telur.

City Planning: The collection of a robust data basis at the building and apartment level is essential for the gradual spatial mapping analysis. It is a key tool for the decision-making process and specifically for identifying the most suitable fossil heating replacement strategies for each area of the city. While there are not yet any local legislations that require municipalities to develop these plans, Decarb City Pipes 2050 offers Bilbao the perfect ecosystem to build up this mapping.

Pathway to climate neutrality and Heating & Cooling Outlook

Introduction

The heating and cooling pathways the city of Bilbao is exploring have been constructed around the city vision of a fully electrified heating and cooling of buildings by 2050. As described in the city's heating and cooling plan, this transformation will require the substitution of all fossil fuel combustion systems for other sources of heat, driven by electricity. These sources will vary from individual electric heating devices (Joule effect) to individual aerothermal heat pumps, to collective systems based on geothermal exchange or connection to heating and cooling networks with diverse sources for heating and cooling (e.g. waste heat, hydrothermal, geothermal, etc.).

This heating and cooling roadmap for 2050 will contribute to this goal of electrification and ensure high efficiency of the overall heating and cooling strategy, for example by trying to avoid the deployment of direct electric heating devices and promoting low-temperature heating and cooling networks in certain areas of the city. A shorter-term action plan for the building sector is being currently developed for the SECAP, with actions being detailed for the next years and up to the 2030, further contributing to the reduction of the heating and cooling demand, and the substitution of fossil fuel boilers.

The detailed characterization of the buildings stock performed within the Decarb City Pipes 2050 project has provided a good basis for both these short and long-term strategies, and to define potential solutions in different parts of the city.

Heating and Cooling in 2050

The current rate of building energy refurbishment is very slow, covering below 0,5% of the building area annually. Even if this rate is increasing to 1%, 1,5% and even 2% in the coming years, about half of the building stock will likely remain without deep renovation interventions by 2050. The overall demand for space heating is therefore expected to be reduced until 2050 by around 20-30%, which is not so significant. Hot water demand, which currently accounts for about 40% of the heat demand in residential buildings, is expected to keep stable and become progressively the larger final use of heat. The cooling demand, on the contrary, is likely to increase. From being currently practically inexistent in the residential sector, it will start being required due to factors such as expected climate change and increased insulation levels in buildings.

Overall, total energy demand for heating and cooling is therefore not expected to change dramatically. The energy sources and technical building systems to supply the demand will be therefore key for the heating and cooling transition.

Final Energy Use for Heating and Cooling by 2050

The SECAP 2030 includes various actions aligned with this heating and cooling roadmap, including promotion of electrification of thermal loads and the development of pilots for highly

efficient thermal networks. In this line and considering a longer-term vision, the Heating and Cooling Outlook envisages the following final energy uses for the residential and tertiary sectors.

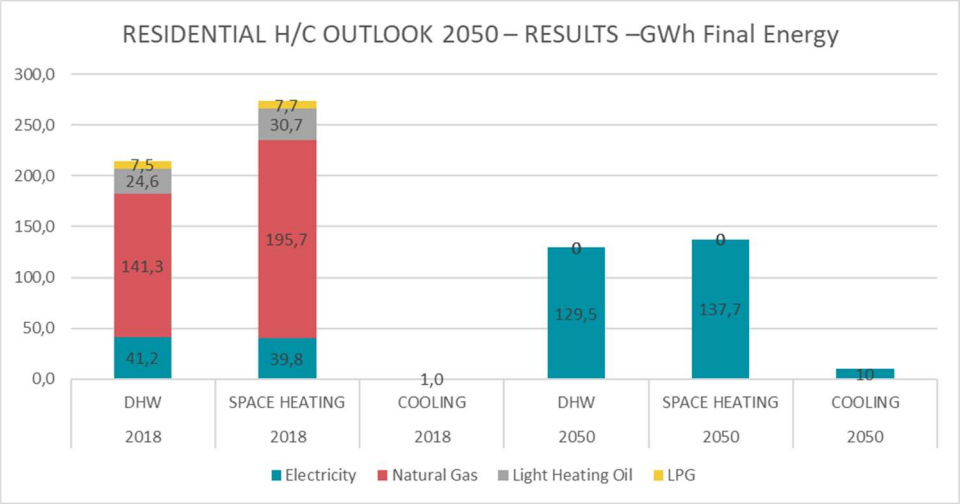

FIGURE 13: RESIDENTIAL H/C OUTLOOK 2050

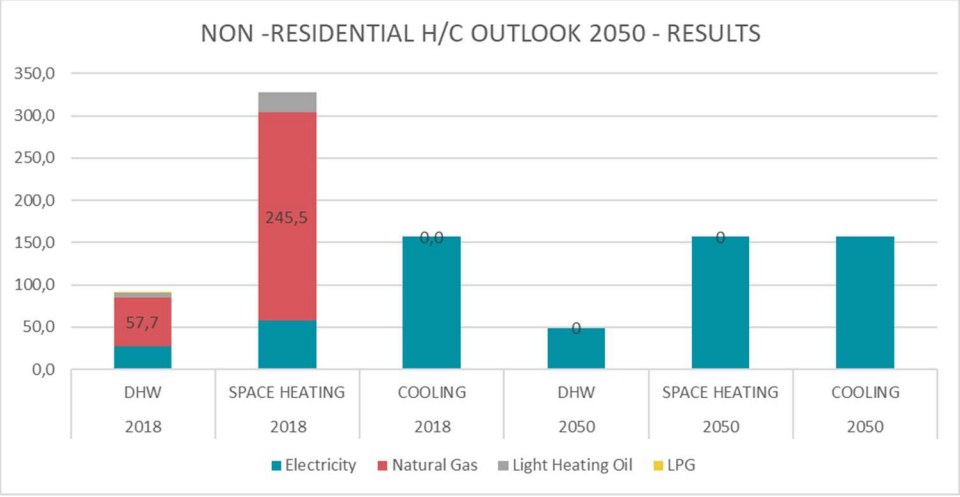

FIGURE 14: NON-RESIDENTIAL H/C OUTLOOK 2050

As can be observed in Figure 13 and Figure 14, the aim is to have an all-electric heating and cooling supply in buildings by 2050, supplied by highly efficient heat pumps, both at building or apartment level, and through heating and cooling networks.

This electrification of heating, which will result in an overall reduction of final energy use of more than 50%, will represent, however, a large increase of the total electricity energy use by circa 200GWh, which is around an additional 20% of Bilbao's total electricity use in 2022.

This highlights the need of integrated planning for heating and cooling together with electricity infrastructure, particularly considering that electric mobility, the other large electricity user besides electrified heat, will also lead to higher electricity demand.

Heating and Cooling (H/C) Plan 2050

An initial geospatial analysis of the heating and cooling requirements in the city of Bilbao has been developed as part of Bilbao's Heating and Cooling Plan.

For the development of the H/C Plan, different sources of information were used. As a base GIS layer, the energy demand calculated per square meter, as well as the configuration of the heating distribution within buildings (centralised or individual) and the current energy source were mapped. This information was extracted from a model developed using basic information from the cadastre as input data, from which building characterising and heating and cooling schedules are inferred. Hourly heating and cooling demands are calculated, and fuel consumption and its associated costs and emissions can also be deducted using data from energy certificates regarding the installation type and fuel. After these calculations from the building stock energy model, results have been adjusted using real data regarding total energy consumption of the city, provided by the energy distribution companies.

Figure 15 shows the calculated heat demand for each of the buildings in the city of Bilbao.

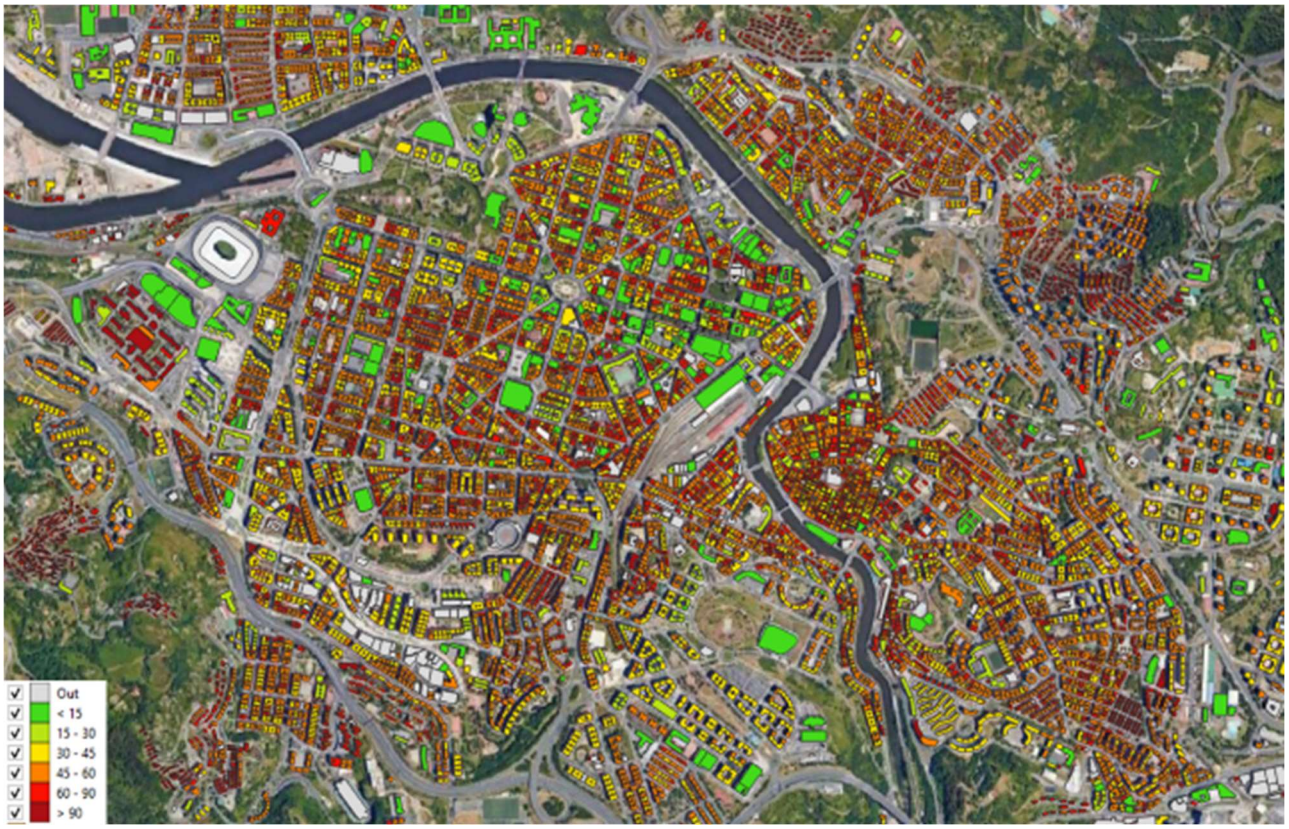

FIGURE 15: HEATING DEMAND [KWH/M2] FOR THE BUILDINGS IN THE CITY OF BILBAO

In addition to these data layers on heating and cooling use, energy source and heating system configuration, further layers were considered in the analysis, which are relevant to inform decisions about where to implement different types of solutions for decarbonising the heating and cooling systems:

- **Potential Heating/Cooling Energy Sources**: Proximity to available heating or cooling sources, which could exchange heat with a district network. The availability of waste heat, geothermal or hydrothermal sources for heat exchange, can improve the economic viability of district heating or cooling networks.

- **Available public space**: Availability of public space for the construction of necessary infrastructure.
- **Protected buildings**: Historic buildings or protected parts of the envelope that do not allow for retrofitting or rooftop installation of elements such as photovoltaic panels or external units for heat pumps.
- **Public buildings**: Buildings owned by public bodies such as the municipality or the Basque government. These are buildings which have a specific requirement for decarbonization under the Basque Energy Sustainability Law 4/2019, and where implementation of low-carbon strategies has become a priority.
- **Degraded areas**: geographical delimitation of degraded areas. These areas have access to subsidies for the implementation of energy efficiency and refurbishment strategies, and integral regeneration projects are more likely to be developed.
- **City plans** (future and incorporated): Plans for new developments or urban regeneration currently incorporated in urban planning or defined future plans.

The consideration of all these layers has served to explore where in the city of Bilbao different strategies could be more relevant, giving a first overview of where heating and cooling networks could be more feasible, or indicating areas more suitable for individual solutions (heat pumps) or for deep refurbishment.

Figure 16 shows and example of a “hotspot” analysis for heating and cooling networks. Areas in red indicate locations in the city where networks could be more viable, based on the weighting and aggregation of all the geospatial information previously gathered.

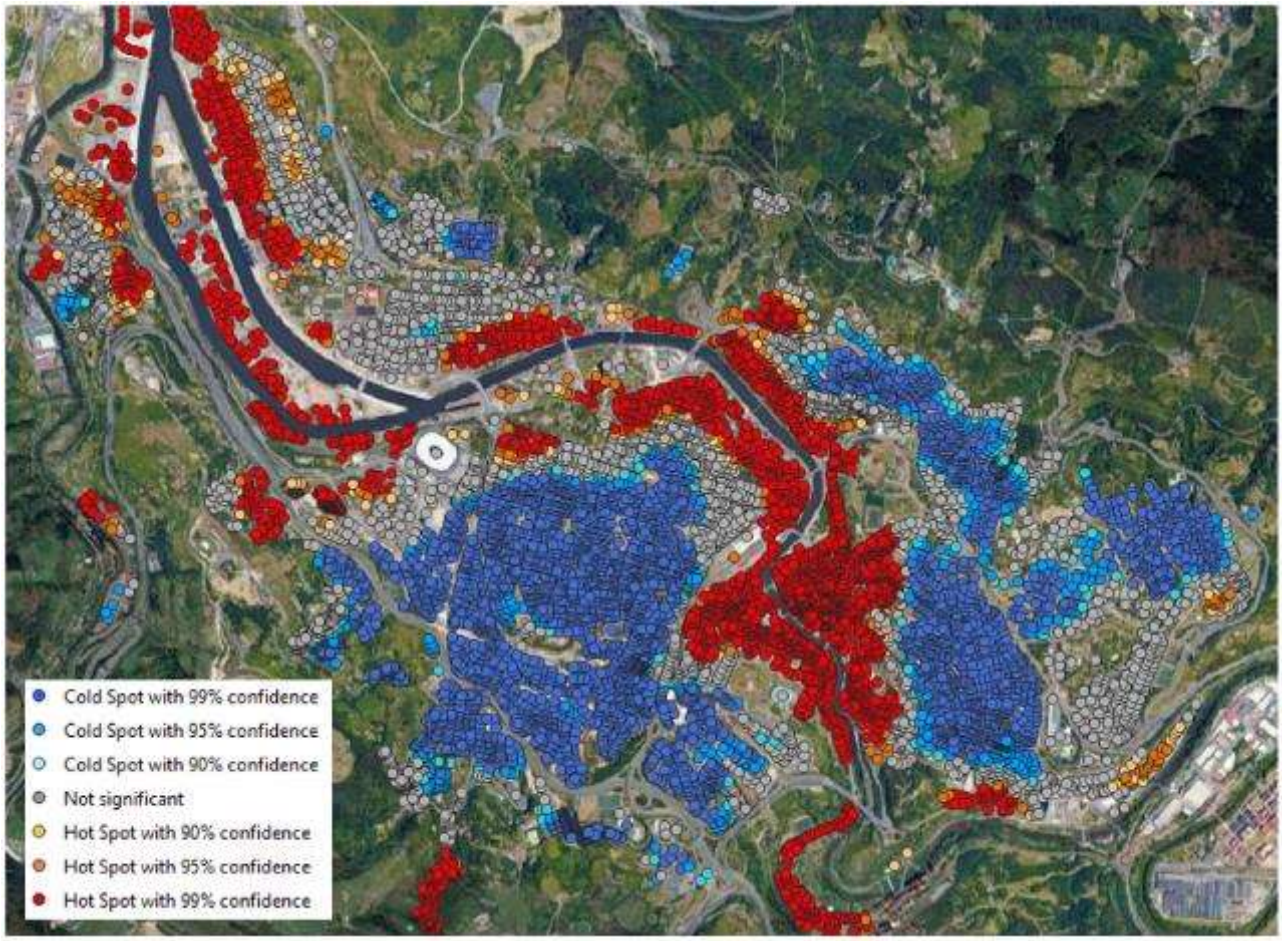

FIGURE 16: HOTSPOT ANALYSIS FOR DISTRICT HEATING AND COOLING NETWORKS

This geospatial analysis will contribute to the decisions about which technologies for electrification of heat (building level heat pumps or district networks) are used within different areas in the city, to be able to reach the vision of an electrified heating and cooling system.

Levers and Instruments

What is the basis to advance towards the decarbonisation of thermal sector? It is a very complex question and perhaps difficult to answer categorically at the moment for the city of Bilbao. It requires an elaborate and meticulous study that tackles the situation from different angles: technically, economically, socially.

This section includes a first description of the identified exploitable instruments or levers in order to achieve GHG emission reductions at city level and the substitution of fossil fuels by renewable energies.

Instrument 1: Energy Spatial Plan

As described in the previous section, the city of Bilbao has a geospatial energy map referenced at building level, which is particularly valuable for the selection of most suitable decarbonisation strategies in each area of the city. There are still new layers of additional data to be incorporated in order to provide an added value to the tool and enrich the decision-making process.

Firstly, it would be advisable to automate the aggregation of data received from the electricity distribution companies and the natural gas network operators through a periodical input in order to keep the map up-to-date. In addition, the current tool needs to be merged with the existing GIS platforms of the local administration which include urban planning infrastructure data. Additional new layers will be beneficial and refine the map, i.e. existing sources of waste heat in the city such as server centres, underground vents, supermarkets because of their need for cooling, or the sewage network. Besides that, collecting data on the electricity grid, as well as on the current renewable production and the potential of generation, on the points of streetlights and their consumption will also be beneficial for completing the mapping.

In fact, the more detailed the map is, the higher the accuracy that can be achieved for determining the prioritisation of strategies by district. In short, the mapping should result in more specific feasibility studies of diverse decarbonisation solutions. As an example, in the areas where centralised thermal systems have been found to be highly viable, the intention is to develop not only a thorough technical report (on pipelines, energy sources, etc.), but also an economical evaluation, defining potential sustainable business models. It is particularly relevant to explore the role of the administration as well as the possible involvement of energy companies or even natural gas network operators. It is also of course important to analyse the case studies of individual solutions (building level, house level) that can be undertaken through heat pumps.

Instrument 2: Municipal Work Structure

A solid and robust working group specifically devoted to the phase-out of fossil fuels is required at municipalities to drive the process. Decarb City Pipes 2050 is a starting point

project in this field for the Bilbao City Council and does not involve the participation of many relevant departments yet. Until now, the Sustainability Commission has been leading the Local Working Group, but its task is limited to fulfil the Sustainability Commission targets.

In this regard, the recent foundation of the BioArtigas energy agency is a key milestone for the city since energy efficiency issues will acquire higher relevance. BioArtigas is a public-private partnership constituted by the City Council and the Basque Energy Agency, which will be responsible of defining the city's long-term Environmental Strategy, cooperating transversally with all City Council departments and establishing the energy-related interventions in the city. It is then decisive that the agency takes over more responsibility and that more resources in terms of budget and workers are added in the following years. Training sessions for workers are also planned in order to increase the agency’s capacities.

Instrument 3: Legal framework

There is no national, regional or local legislation specifically prohibiting the use of fossil fuels for heating and that is highly unlikely to change in the short term. The intention is to take advantage of the project learnings and disseminate the outcomes in order to raise the awareness of authorities for setting a regulatory framework enabling the heating transition. This is the only way to speed up the process. As a result of the project, the municipality intends to set a closer coordination with regional and state regulations to assess the benefits of heat networking and to try to suggest legislative changes. At the same time, it is also important to review local regulations that hinder the implementation of alternatives to fossil fuels (e.g. prohibition of the use of roofs for installing aerothermal equipment).

Instrument 4: Social awareness

Public awareness and capacity-building sessions are crucial elements to achieve the goals set. The City Council has to think about innovative channels to inform the general public about alternatives to fossil fuels, and about taking energy efficiency actions. However, it is not an easy task to reach out to citizens. Incentivising measures, such as subsidies or grants, are potential strategies in order to promote energy savings interventions among residents. On the other hand, in some cases, "one-stop-shop" offices can be helpful due to their proximity to residents. Several big-scale retrofitting projects in Bilbao used this option with a high level of satisfaction and it could be replicated especially for those areas where DH is to be implemented.

Instrument 5: Training sessions for workers

Nowadays, there is a clear lack of knowledge and expertise in the heating sector about renewable solutions. With the aim of closing that gap, regular training courses for professionals (installers, architects etc.) could be given by the Basque Energy Agency.

The Road Ahead

The City of Bilbao has undertaken a great transformation over the last decades from a fully industrial area to a city focused on tourism, services and knowledge. All the construction works and interventions developed along the years have been based on an urban sustainable planning context and with the purpose of attaining a better quality of life for residents. In line with that strategy, the city has recently also started several energy and sustainability projects, submitting the Bilbao 2050 Environmental Strategy or by being part of the Covenant of Mayors.

Nevertheless, regarding the heating and cooling sector, the Decarb City Pipes 2050 project has been the trigger point for focusing on the impact of space heating, cooling and domestic hot water consumption. Due to the mild climate in southern Europe, “decarbonisation” is usually linked to decarbonising electricity production. This project has, however, highlighted the relevance of the heating and cooling sector and explored ways for replacing the widely used natural gas boilers in the city as well as old oil boilers with other renewable solutions. In a first approach, the city assumed that massive retrofitting would be a practical measure to lower the energy demand and reduce the dependence of fossil fuels. However, given the low renovation rate for residential buildings, the fact that domestic hot water represents a significant ratio of total heat demand, and considering the expected increase demand for cooling, the city is committed to proactively adopt other measures to decarbonise heating and cooling.

The final goal is to achieve high energy efficiency performances and emission-free standards at building level through sustainable business models and affordable schemes for citizens, and by involving the adequate stakeholders. Local circumstances are also critical to design a tailoring plan. Most of the buildings in Bilbao are privately owned condominiums (multifamily properties), with a rather aged population and with a private operator of the gas network and that context determines the rhythm of the actions.

The H/C Plan developed in the project is a first conceptual valuable tool to select the most suitable strategies (individual solutions such as heat pumps, centralised district heating…) depending on the features of each district. The main outcome of that plan is a mapping that aggregates diverse layers of data: urban planning data, energy data and potential renewable production, buildings characteristics. The GIS developed gives a comprehensive overview of the convenience of renewable solutions in each area. Further analysis including additional information and a cost-benefit evaluation will be needed to advance towards heating and cooling decarbonization in the city.

The City of Bilbao is aware that there is a lot of work ahead and that more resources are necessary. In this regard, the recent creation of the BioArtigas energy agency is a key milestone for the city since energy efficiency issues will acquire a higher relevance. It will shape the city's long-term Environmental Strategy and ensure transversal cooperation across all City Council departments.

Upcoming steps will include the improvement of the mapping exercise, integrating new additional layers of data, such as the existing sources of waste heat or the electricity grid data. More accurate conclusions will be then be possible and certain specific analyses for

business cases are expected to be undertaken. As an example, Halmstadt University in cooperation with Tecnalia is working on a technical and economic study of a centralised district heating in an area of the city with appropriate conditions. While these reports need to be carefully evaluated by the local administration, they will be in line with and support the efforts laid out in the city's SECAP.

DECARB CITY PIPES 2050

Transition Roadmap City of Dublin

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 893509

Transition Roadmap of Dublin

Introduction & Context

Heating is a hugely important sector in Ireland when it comes to decarbonisation as it represents approximately 40% of energy demand (twice the demand of electricity) and is the worst performing sector in terms of renewable proportion (currently at 6.3% of total heat production) behind both electricity and transport.

The district heating networks potential to enable greater uptake of renewable and waste heat sources is shown in the figure below, where there is a strong correlation between DH and renewable heat proportions. This relationship is now being recognised in national heat policy.

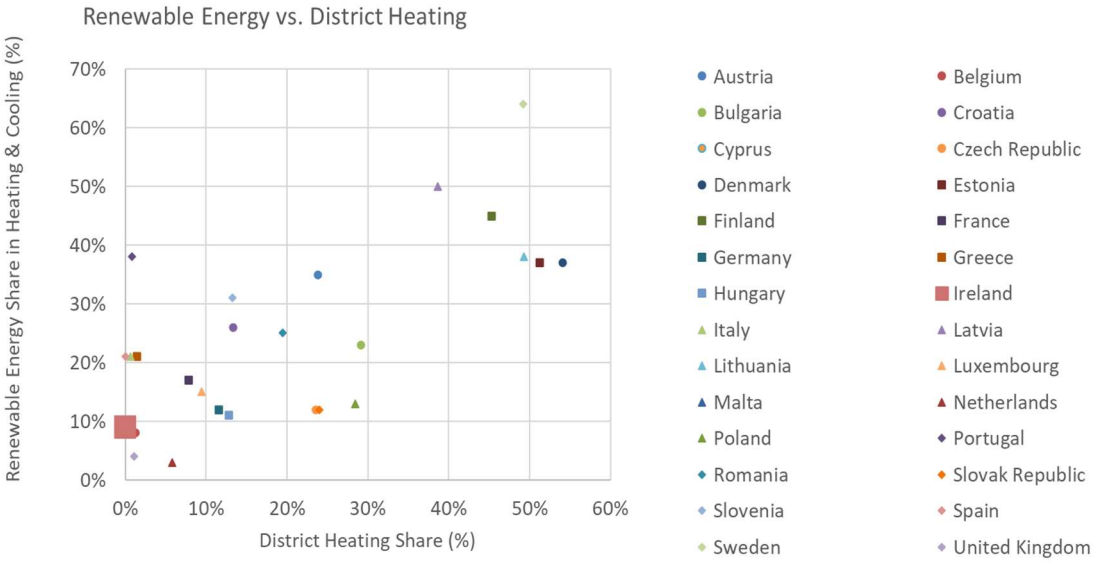

FIGURE 17: RENEWABLE ENERGY VS. DISTRICT HEATING IN EUROPE

The majority of buildings in Dublin currently use gas-fired heating. The gas grid covers practically the whole city, developed at national level by semi-state-owned companies without considering where DHC grids may be a better option. Figure 18 shows the breakdown of types of heating technologies currently installed in Dublin. Gas is by large the dominant heat fuel followed by direct electric (not heat pumps), particularly in the inner city where many apartments are heated in this way. The current distribution of fuel sources in residential dwellings reads: Gas 74% (assumedly mainly individual boilers), Electric 18% (mainly direct electric rather than heat pumps), Oil 7%, and Coal/Biomass 1% (percentages relating to the share of dwellings supplied by each respective fuel source).

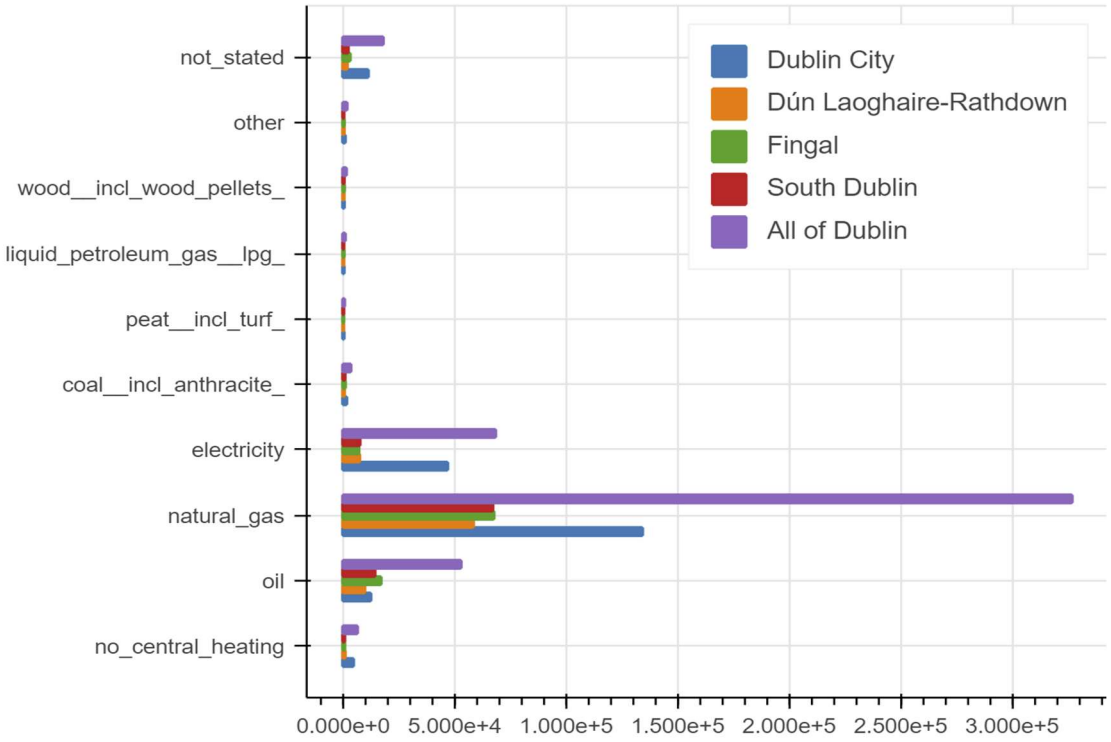

FIGURE 18: TYPES OF HEATING TECHNOLOGIES CURRENTLY INSTALLED IN DUBLIN

Currently, the heating sector has a very low penetration of renewable energy, and Ireland is the worst performing country in the EU in this regard with a renewable heat proportion of just 6.3%. The Climate Action Plan states that all buildings will need to switch to heat pumps or district heating by 2050, meaning that the gas grid will no longer supply existing homes and commercial premises.

District heating is a new technology in Ireland, currently representing less than 1% of the heat market but with potential for this to be between 57% and 54% based on a 2019 study performed by the Heat Roadmap Europe researchers and results from the SEAI's National Heat Study[12], respectively. The potential for DH has been recognised in the national Climate Action Plan 2023 where a target of 2.7TWh of heat is to be supplied via DH by 2030 (and 0.8TWh by 2025). This 2.7TWh target represents 10% of all residential and commercial heating in the country.

To support this roll out of DH, there are also actions in the Climate Action Plan 2023 where the government will:

- Support through the Climate Action Fund
- Establish a system of governance for the development of district heating policy
- Perform research to support the rollout of district heating in Ireland
- Develop a regulatory framework to protect customers & suppliers
- Ensure planning framework encourages and facilitates the development of DH – zoning of areas for DH
- Identify appropriate financing mechanisms to support delivery of DH including financial incentives similar to retrofit grant programs

[12] https://www.seai.ie/data-and-insights/national-heat-study/

- Update relevant regulatory & legislative tools to enable roll out of DH infrastructure

There is an agreement today that more bottom-up effort is required, but municipalities have a very low level of autonomy trying to find paths through their limited remit to influence the use of energy and emissions in their regions and limited municipality resources.

Importantly, Dublin has used its local working group – newly established specifically for this project – to identify actions to advance Dublin's heat transition, policy and buy-in to the low-carbon heating/cooling transition needed to overcome barriers to the roll-out of other alternatives to gas grids. The Dublin Local Working Group is made up of local, regional & national level stakeholders who are fundamental to the success of the roll-out of low carbon grids in the city.

Dublin has become a pioneer in Ireland for local level energy planning and DHC implementation, both of which are completely new practices in Ireland. Codema, as the energy agency for Dublin, has been building these skills and practices with the Dublin municipalities through numerous EU & national level projects. The municipalities have now committed to developing a city-wide DH scheme, outlined in the "Dublin City Climate Change Action Plan 2019-2024". Using learnings from the Policy Experiment (WP5) of the Decarb City Pipes 2050 project, Dublin City Council have also introduced a requirement, as part of the City Development Plan, for Energy Statements to be produced for any developments greater than 1,000 m^2 (commercial space) or 30 dwellings. The ongoing learnings from implementing this policy are also being used to refine this process.

Dublin has made significant progress in DH in the last few years. The first large-scale DH network in the county (Tallaght DH Scheme) is now operational. This DH network is the first not-for-profit public utility in the country and the first to use data centre waste heat as its heat source.

The development of a much larger DH network in the Poolbeg & Docklands area of the city is also progressing. This network will use waste heat from the Dublin Waste-to-Energy (WtE) plant as its inital primary heat source. A preliminary business case report has been produced for this project as well as extensive engagement with customers and energy service companies (ESCOs) who may be responsible for the construction and operation of the proposed network. This project is expected to go out for procurement in 2023. There has also been significant progress made in planning policy in the city to support DH, with requirements for buildings to "futureproof for connection (making buildings technologically ready to connect to DH) in certain areas of the city. €20 million in funding has also been secured for this project's development.

A feasibility study for another DH network using data centre waste heat has also been developed for the Blanchardstown area and the results of this study are currently being considered by the local municipality.

Further opportunities in areas such as geothermal DH and greater sector integration with the electricity sector (using DH + thermal storage to reduce the curtailment of renewable electricity generators) are also being progressed within Dublin.

City Profile

The table below summarises the profile of Dublin which can quickly allow other cities to see where they might have similarities.

Is heat planning mandatory in this city?	No but it has been carried out as part of the Dublin Region Energy Masterplan. Output maps on heating are available here - https://codema-dev.github.io/posts/
% of heat supplied by DH	<1%
Predominant heat source for DH	Waste heat from Data centres & WtE plant
What generation of heat networks?	3rd and 4th generation
DH ownership	Currently mainly publicly owned
National or regional targets for DH?	National target of 2.7TWh of DH by 2030 and 0.8TWh by 2025
Is there strong local engagement	Commitment from Dublin City Council to deliver DH in Dublin. This is reflected in the most recent City Development Plan where new developments of a certain size are required to be DH-enabled where feasible. Also, DCC are developing their own DH network using waste heat from Waste-to-Energy plant.
Predominant existing heating type	Individual gas boilers
Heat sources with the highest potential in Dublin	Power plants, wastewater treatment plant, geothermal, surface water, sea water

Dublin's H/C Plan – The 2050 Goal

Dublin's Heat Decarbonisation Pathway

The sections below summarise the heat sources available for use in DH networks and what are the preferred heating technologies for different areas of Dublin. This pathway was determined by the lowest cost of carbon abatement in the heating sector for DH vs ASHPs (air source heat pumps), (including Capex, Opex, Repex and CO_2 equivalents from methane and refrigerant leaks) for the period up to 2030 and 2050 (i.e. not just in that year). The key metric used was the €/tCO_2 saved. The results of this analysis can be seen in Figure 19.

The areas coloured blue are most suited to heat pumps and the areas coloured red are most suited to district heating. The darker the colour the more suited that area is to either technology.

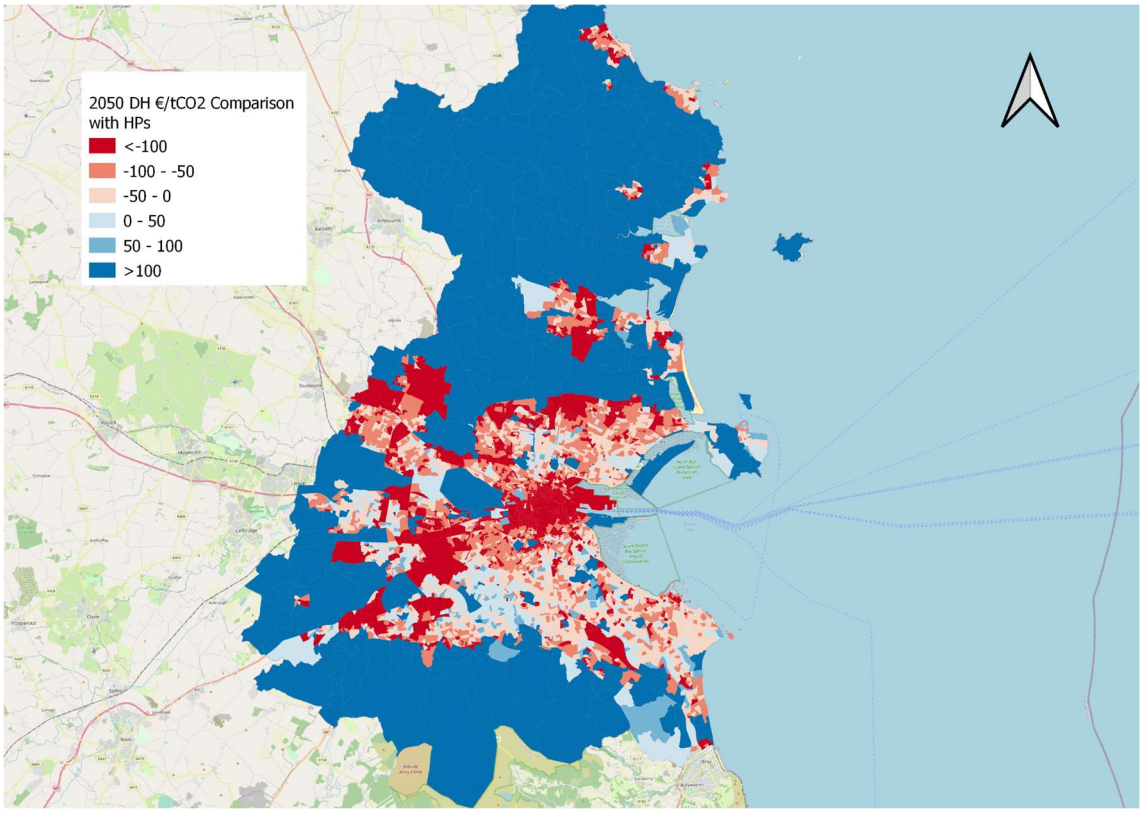

FIGURE 19: 2050 DH AND HP PRIORITY AREAS BASED ON LOWEST NON-DISCOUNTED CARBON ABATEMENT COST

By 2050, district heating represents the best option for 9.06TWh (87%) of heat demand in terms of cost-effective decarbonisation. By 2050, it is assumed that the required supply chain is in place to deliver on the full DH potential outlined. This would save 1,550.1 $ktCO_2$ in carbon emissions and 617.6 $ktCO_2eq.$ in equivalent emissions in the year 2050.

The underlying assumptions and analysis which informed this map and resulting contribution fo both DH and individual heat pumps are discussed in the analysis section below.

Underlying Analysis

The decarbonisation of the gas grid is limited by the capacity to produce biomethane and by the current technical restriction on using hydrogen in existing gas infrastructure (see emissions factors in Figure 20).

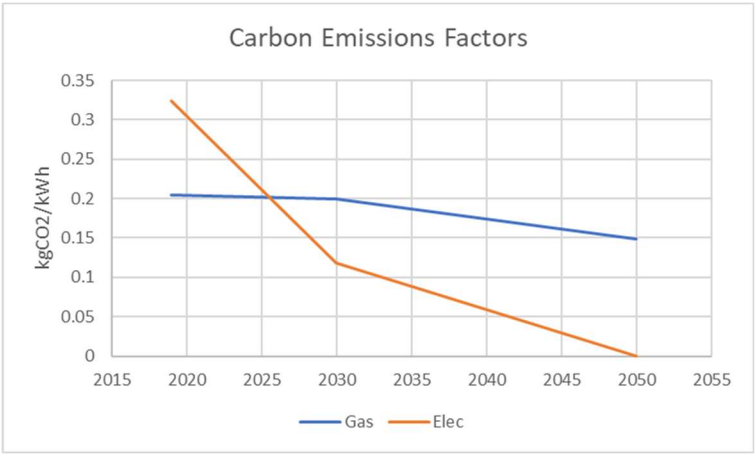

FIGURE 20: CARBON EMISSIONS FACTORS

Green hydrogen not considered suitable for low-exergy applications such as space heating and hot water preparation due to inherent inefficiency when compared with alternatives. It is also assumed that all future buildings will be nZEB, and various fabric upgrade options were considered for existing buildings.

Heat Sources in Dublin

The graph below shows the range of 18 heat sources investigated by Codema for heat planning purposes and also includes typical temperature ranges for each heat source, and highlights how that matches up against potential end-use temperature requirements.

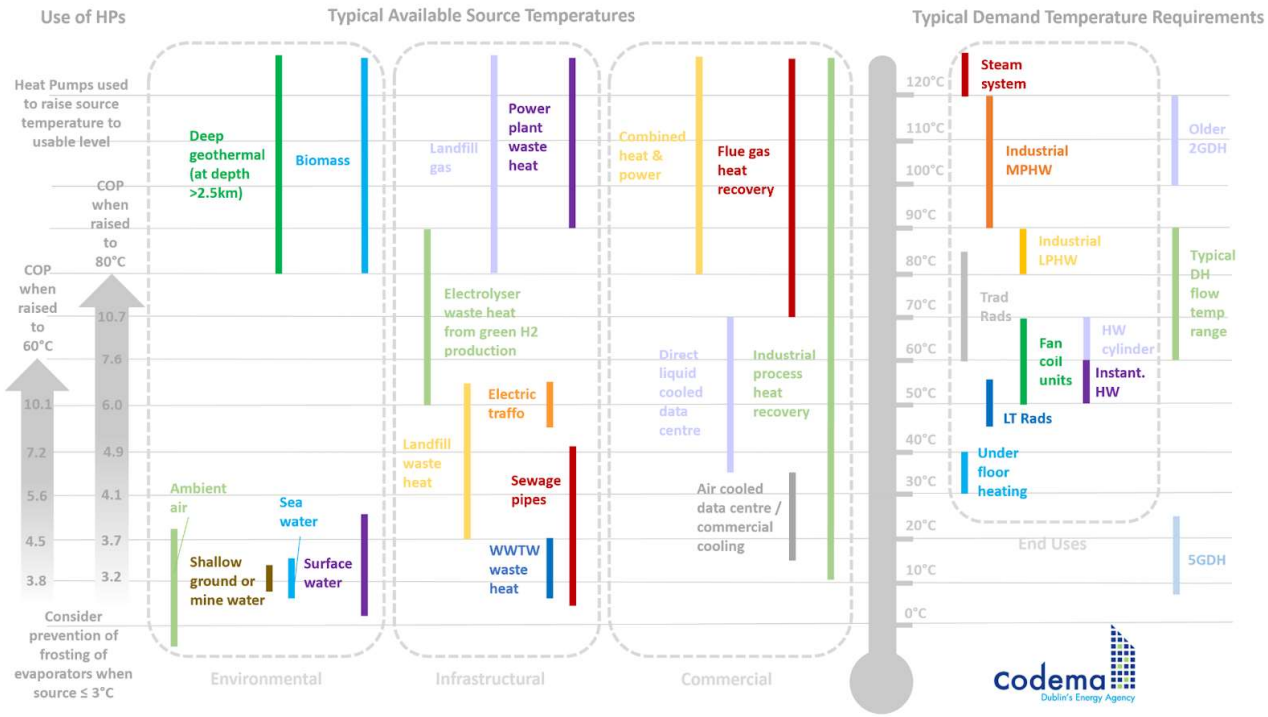

FIGURE 21: HEAT SOURCE AND END-USE TEMPERATURES

Figure 22 shows the breakdown of heat sources available in Dublin for the current and future scenario. It can be seen from this graph that the main changes over this period is the significant reduction in heat available from power plants as renewable electricity generation increases. This reduction is offset by increased heating potential from data centres and from renewable electricity generation which would otherwise be curtailed. Identifying some the main potential heat sources has helped to define some technology-specific actions in the this transition roadmap, particularly for data centres and geothermal.

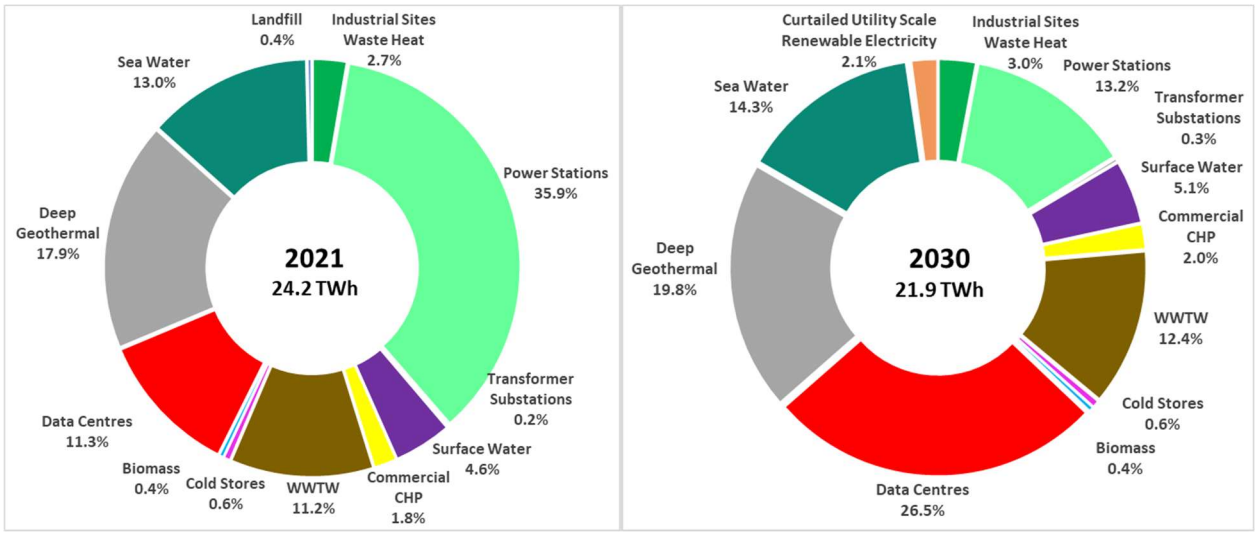

FIGURE 22: HEAT SOURCE BREAKDOWN FOR 2021 AND 2030

The location of these heat sources (totalling approximately 530 sources) is set out in the map below (Figure 23) and can also be found online[13].

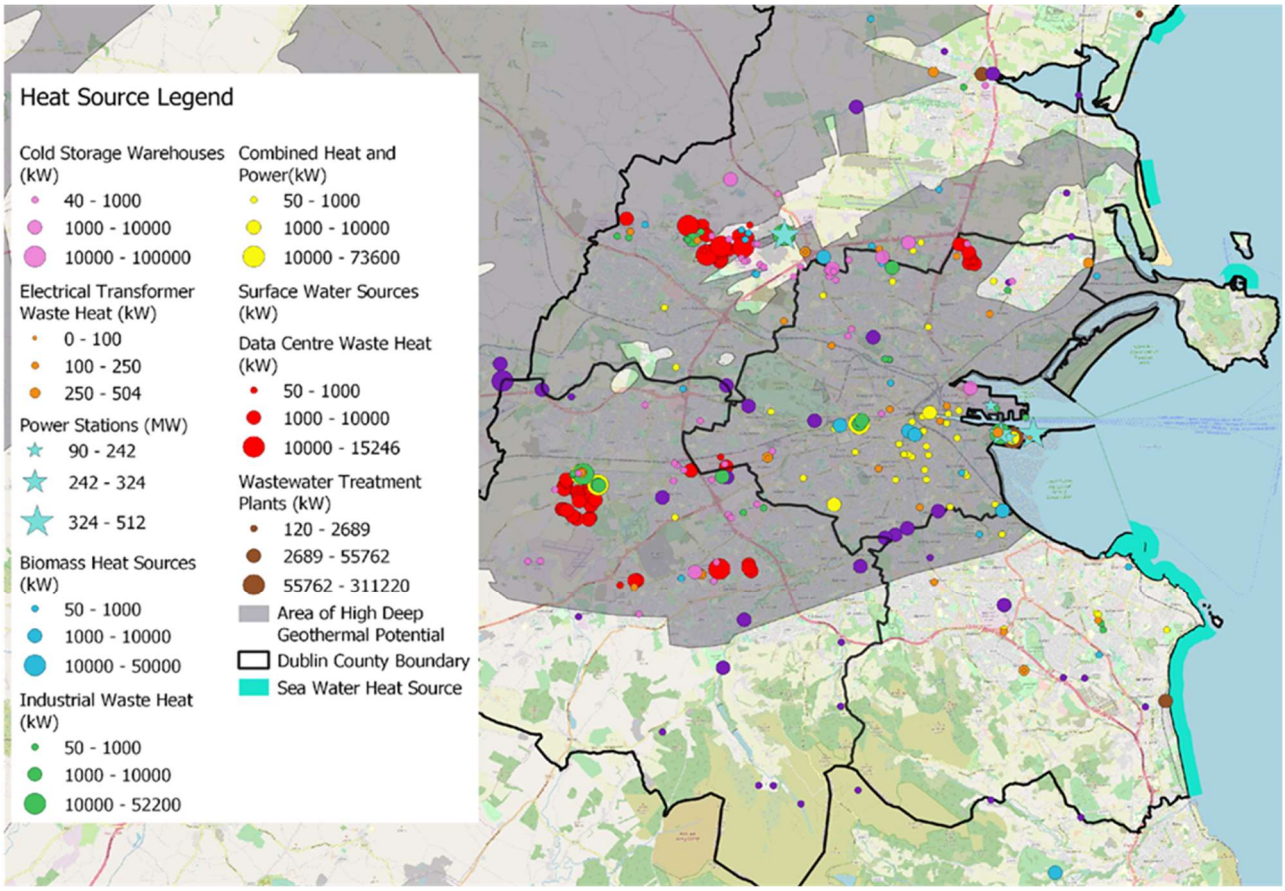

FIGURE 23: HEAT SOURCE MAP OF DUBLIN

These sources have been broken down based on their average supply temperatures in the graphs below (Figure 24). This provides an indication of the quantity of higher temperature heat that could be utilised for direct use in DH networks (>60°C) without requiring heat pumps. The medium temperature sources which can supply heat between 20°C and 60°C would likely require a heat pump to bring them up to a usable temperature for typical DH networks but these could achieve very high COPs (coefficients of performance), likely to be

[13] https://codema-dev.github.io/map/heat-source-map/

above 3.5 and perhaps up to 12 (i.e. 12 units of heat for every 1 unit of electricity). The low temperature range (<20°C) would require heat pumps to raise their temperature to a usable level. Even when using the same sources as individual building heat pumps, these large-scale heat pumps generally provide better COP than the smaller alternatives. This is due to a number of reasons: these large-scale HPs are continually monitored to ensure their performance is optimised, they have continual maintenance to ensure efficient operations, the diversity of loads being supplied lends itself to less short-cycling of the heat pump improving efficiency and the HP's lifespan, and the economies of scale allow for use of two-stage compression, which improves efficiency when using lower temperature sources.

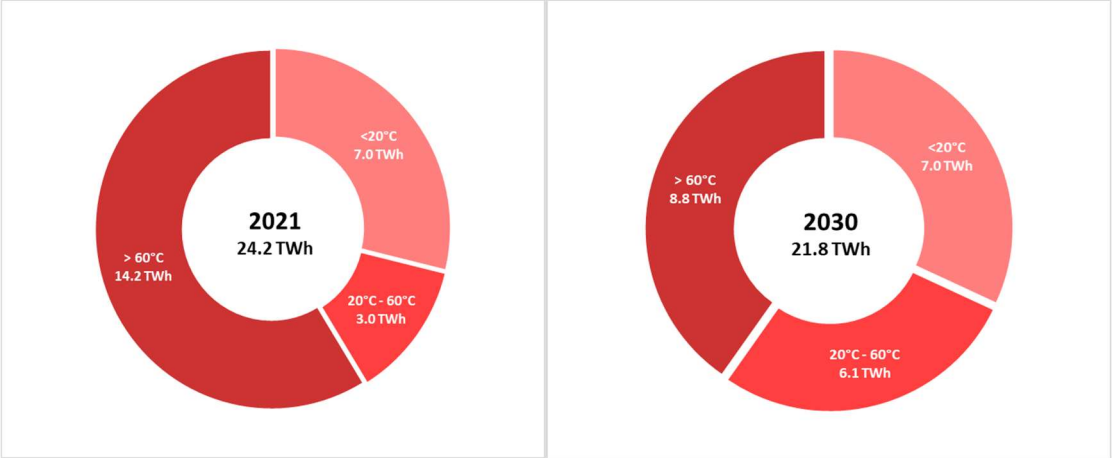

FIGURE 24: HEAT SOURCE BREAKDOWN BY TEMPERATURE FOR 2021 AND 2030

Initial Assessment of Heat Demand

The heat demand was calculated using domestic building energy rating (BER) information for the dwellings for which this was available and these demands were then extrapolated to the full buildings stock based on the age and location of the dwellings for which the BER was not available. Codema created a synthetic building stock model to facilitate this and to allow future fabric upgrades to be analysed. This building stock model allows for the u-value (a measurement of heat transfer) of various elements of a dwellings envelope (walls, windows, etc.) to be adjusted and for a new heat demand to be generated based on these changes. Commercial building heat demands were calculated using the building floor areas and CIBSE [14] benchmarks. Public sector heat demands were based on metered consumption.

The map in Figure 25 shows the heat demand density in TJ/km² for each CSO[15] small area in the county. This metric is one of the key indicators for DH suitability. An interactive version of these maps is available on the Codema-dev GitHub page[16]. The breakdown of demand categorised as very feasible, feasible, not feasible, etc. can also be found on this webpage. Table 8 below provides indicative figures for DH suitability based on this heat demand density metric alone. The DH vs HP assessment in the next section of this report builds on this analysis and directly compares the two low-carbon heating options based on the cost of carbon abatement. Interestingly, the carbon abatement cost analysis shows district heating as a better option for even more of Dublin than the analysis based on demand density alone.

[14] https://www.cibse.org/
[15] Central Statistics Office - Ireland's national statistical office
[16] https://github.com/codema-dev

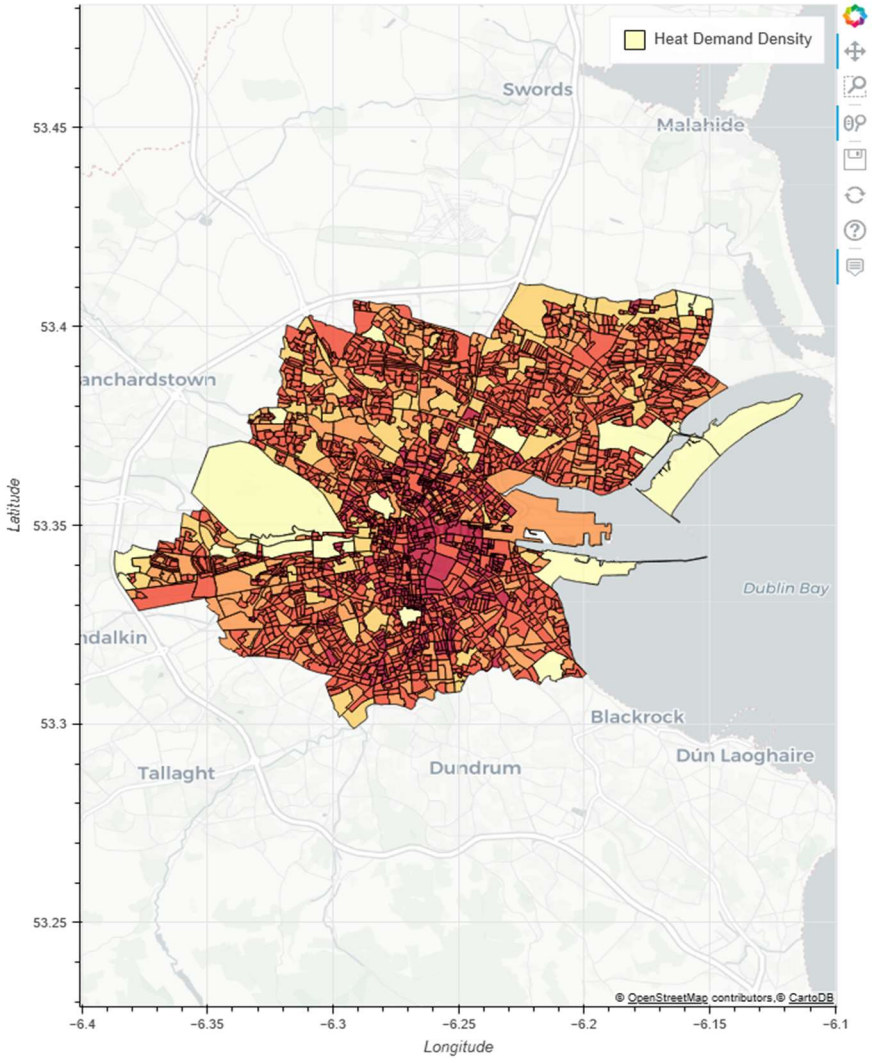

FIGURE 25: EXAMPLE OF HEAT DEMAND DENSITY MAPS PRODUCED

The table shows that 83.5% of heat demand in Dublin city is suitable for DH (above 120TJ/km^2) and that this could increase to 96.6% with supporting regulations in place.

TABLE 8: BREAKDOWN OF SUITABILITY FOR DUBLIN CITY

Feasibility	Residential [MWh/year]	Non-Residential [MWh/year]	Total [MWh/year]	Band [TJ/km²year]	% Share [MWh/year]
Not Feasible	23733	7803	31535	<20	0.7
Future Potential	89688	34996	124683	20-50	2.7
Feasible with Supporting Regulation	430562	172766	603327	50-120	13.1
Feasible	2229477	431259	2660736	120-300	57.7
Very Feasible	627162	561711	1188872	>300	25.8

Final Assessment of DH vs Heat Pumps

Two main heat decarbonisation strategies were assessed; one based on the adoption of district heating networks and the other looking at the widespread adoption of air source heat pumps. This analysis was performed for every CSO small area. The total number of CSO small areas in Dublin is 4,884. The determining factor in choosing one technology over the other was the cost of carbon abatement. The technology with the lowest carbon abatement cost (€/tCO$_2$ abated) was chosen as the preferred decarbonisation pathway. The cost and carbon abatement figure was calculated based on local conditions within each small area as discussed below.

District Heating Costs

The network length within each small area was determined through the use of random sampling. In this sampling exercise, indicative networks were drawn on multiple areas of a certain urban fabric. An example of the network routes drawn can be seen in the map below in red. The network length was then compared to the road centre line lengths from open street map (OSM). This relationship was then used to estimate the network length required within each small area.

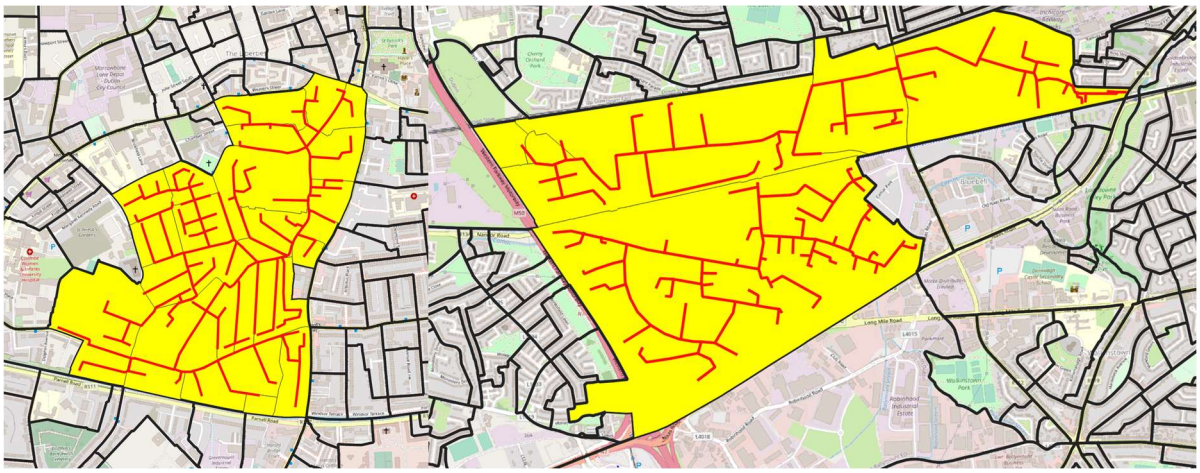

FIGURE 26: EXAMPLE OF NETWORK LENGTH ANALYSIS PERFORMED

The average DH pipe diameter rounded to the nearest standard pipe size was estimated for each small area based on the linear heat density using the following relationship[17]:

Average DH Pipe Diameter (mm) =
*(0.048*ln(Linear Heat Density in MWh per metre) + 0.063)*1000*

The capital cost of the heat production equipment was estimated based on a representative €/kW figure, which includes the capital cost of the main heating plant, backup heating plant, and auxiliary and automation equipment. The kW used to determine the cost was based on an average diversified peak heat demand for each domestic dwelling plus the diversified peak commercial demand based on the calculated annual heat demand and a typical equivalent run hours for commercial buildings.

The cost of heat interface units and heat substations were also included for the DH option based on an average kW peak demand per building.

Heat Pump Costs

The capital cost of the heat pump option was calculated using a figure of €1,200/kW thermal output. This figure assumed air source heat pumps (air to water) were fully installed including fittings, buffer tank, new cylinder (existing cylinders are not deemed compatible with efficient heat pump operation due to the relatively small surface area of their coils) and controls, but excluding the heat distribution system. Excluding the distribution system may mean the cost estimate for an efficiently-operating ASHP system may be slightly underestimated in some cases.

[17] https://hre.aau.dk/wp-content/uploads/2018/09/STRATEGO-WP2-Background-Report-6-Mapping-Potenital-for-DHC.pdf

It is understood that once heat pumps start to represent a significant proportion of the heat market, the cost of heat pumps will reduce as supply chains improve, installation overheads reduce and the equipment cost itself also reduces. This cost reduction is captured in this analysis through the annualised replacement expenditure (Repex) cost, which assumes a 20% reduction will occur[18] within the first lifecycle of the heat pumps, i.e. before 2036.

Whilst not included in this analysis, it is also worth noting that the floor area consumed by the required hot water cylinder also has a cost associated with it. For a build-to-rent apartment in Dublin, this cost is estimated at €2,350 per dwelling, for example. This cost benefit for DH was excluded as the majority of buildings in Dublin are existing buildings and already have hot water cylinders of a similar footprint installed and are designed in such a way that the floor area freed by removing these units is of limited value.

Electrical Grid Upgrade Costs for Heat Pumps

The installation of heat pumps in homes will also have an impact on the electricity grid which, in certain areas, upgrades will be required to serve these new loads. The cost of these upgrades has been estimated for the low volatge (LV) & medium voltage (MV) grid and also for the high voltage (HV) grid using two different approaches for domestic and commercial buildings.

The LV & MV grid upgrade cost adopted was based on costs from ESB Statement of Charges[19]. For existing homes whose current connection (typically 12kVA) will need to be upgraded (assumed to 16kVA) to service additional load from the heat pump (but also potentially EV charging and greater use of electric cookers). This connection upgrade charge is stated as being €1,539 for a single urban connection. This includes MV network costs but excludes trenching within the boundary of the site. Assuming a power factor of 0.95 for the heat pump load, this translates to a LV & MV upgrade cost of €405/kWe. The additional trenching cost is estimated at €6/m based on typical rates. This trenching cost would apply to all new connections but considering that Dublin consists of predominantly existing buildings and the limited impact of such a low cost, this trenching cost has been excluded from the analysis.

For commercial buildings, the impact of heat pumps on the building's maximum import capacity (MIC) was assessed in order to determine if the HP installation resulted in the building breaking its existing MIC threshold and thus incurring additional cost for falling within a higher MIC band. In the vast majority of cases, it was determined that the addition of a heat pump would not result in the building reaching the next MIC price band, but where it does the cost has been included.

[18] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/498962/150113_Delta-ee_Final_ASHP_report_DECC.pdf

[19] https://www.esbnetworks.ie/docs/default-source/publications/esb-networks-dac-statement-of-charges.pdf

Emissions from DH, Heat Pumps and Gas

The graph below shows the emissions (CO_2 and CO_2 equivalents) for the predominent existing heat supply option (gas boilers), individual heat pumps and DH networks (based on heat source mix from DH netowrks being rolled out in Dublin). These figures were combined with the cost information above to develop the cost of carbon abatement which was used to determine the preferred heating option for each small area in Dublin.

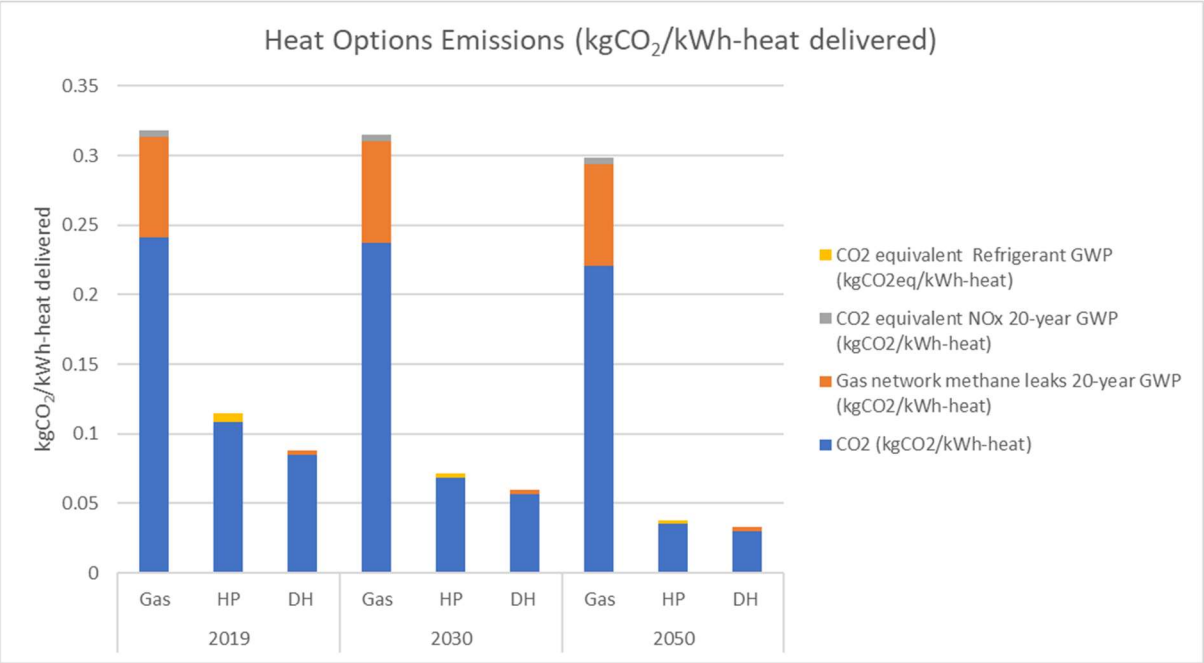

FIGURE 27: EMISSIONS (INCLUDING EQUIVALENTS) PER HEAT DELIVERED BY TECHNOLOGY

Transition Roadmap Development

The development of a transition roadmap (TR) sets out the steps towards achieving the vision from the city's H/C Plan. It is important that the TR is developed in collaboration with key local stakeholders (local working group) to ensure due consideration is given to local conditions and that the actions have the support of those who will be key to its implementation.

In the course of the Decarb City Pipes 2050 project, Dublin developed its Transition Roadmap using the following process:

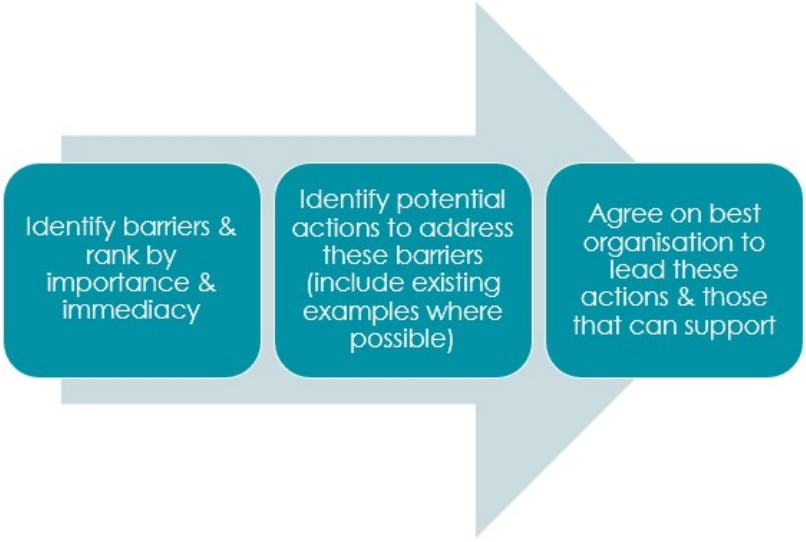

FIGURE 28: TRANSITION ROADMAP DEVELOPMENT PROCESS

The first step was to identify the barrier that would prevent each city from achieving its heat transition targets at the speed and scale required. These barriers were identified through group workshops. In order to help facilitate this process the challenges were considered under some of the headings shown in Figure 29 - political, economic, socio-cultural, techological, environmental, legal (commonly referred to as PESTEL) or under knowledge & skills, resources, regulation policy & planning, technology, mindset awareness & engagement, governance structures & authority and other.

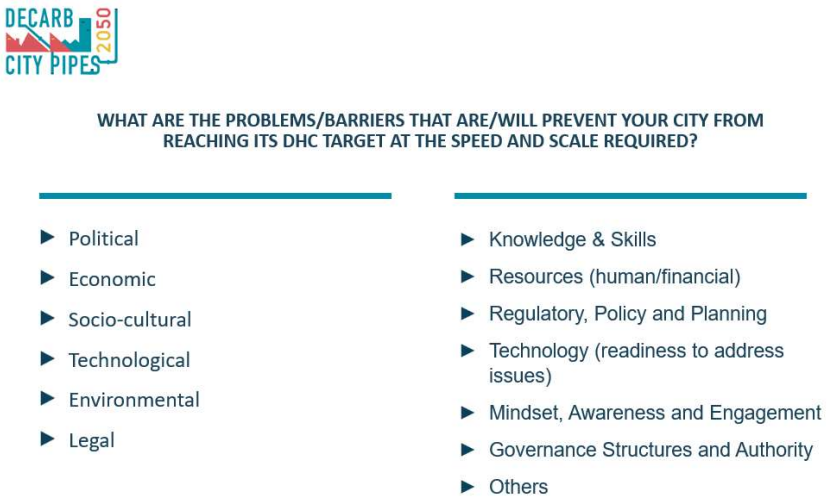

FIGURE 29: PROBLEMS AND BARRIERS THAT PREVENT ACHIEVING A CITY'S DHC TARGET

Following their identification, the barriers were placed into a hierarchy based on their priority and the timeframe in which they should be addressed. The figues below shows the matrix used for this process and some pictures from the workshops where this process was carried out.

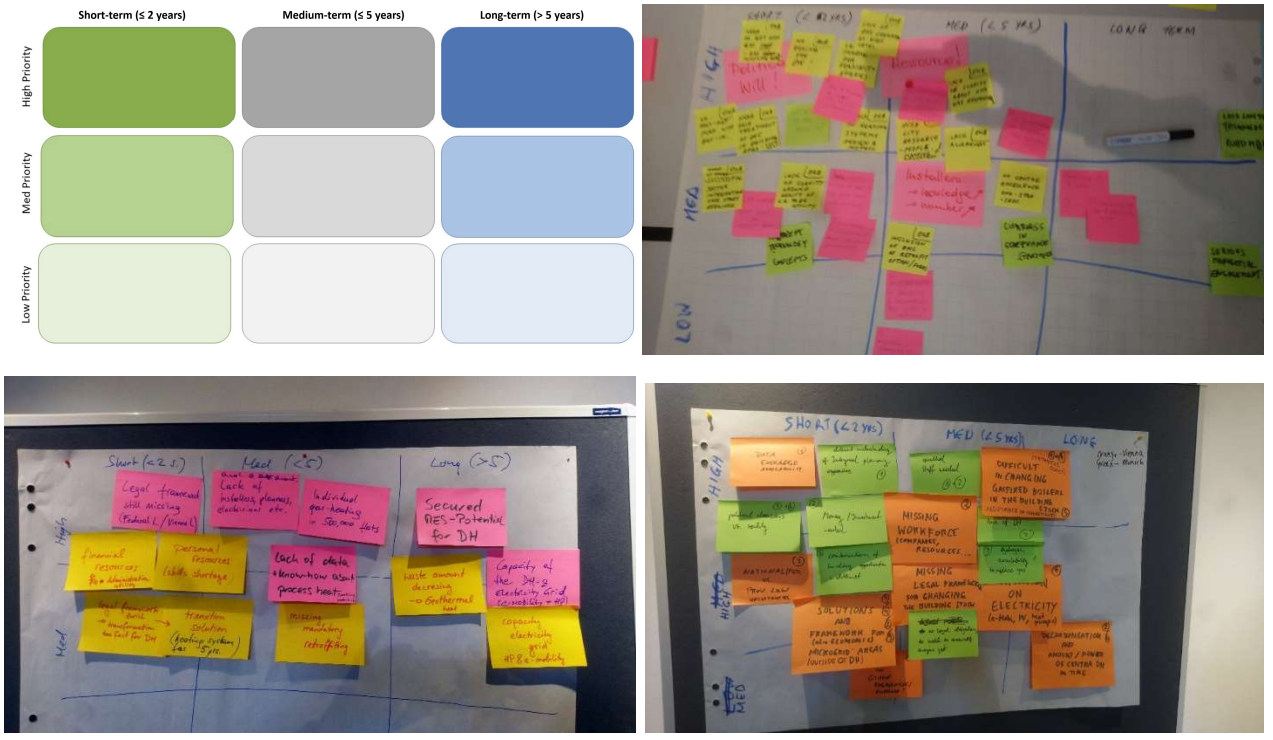

FIGURE 30: PESTEL ANALYSIS

Throughout the development, it is important to have local stakeholders involved in this process. This can often be best facilitated through online workshops using tools such as Miro. The image below shows a Miro board from such local stakeholder engagement which followed the same process as set out above.

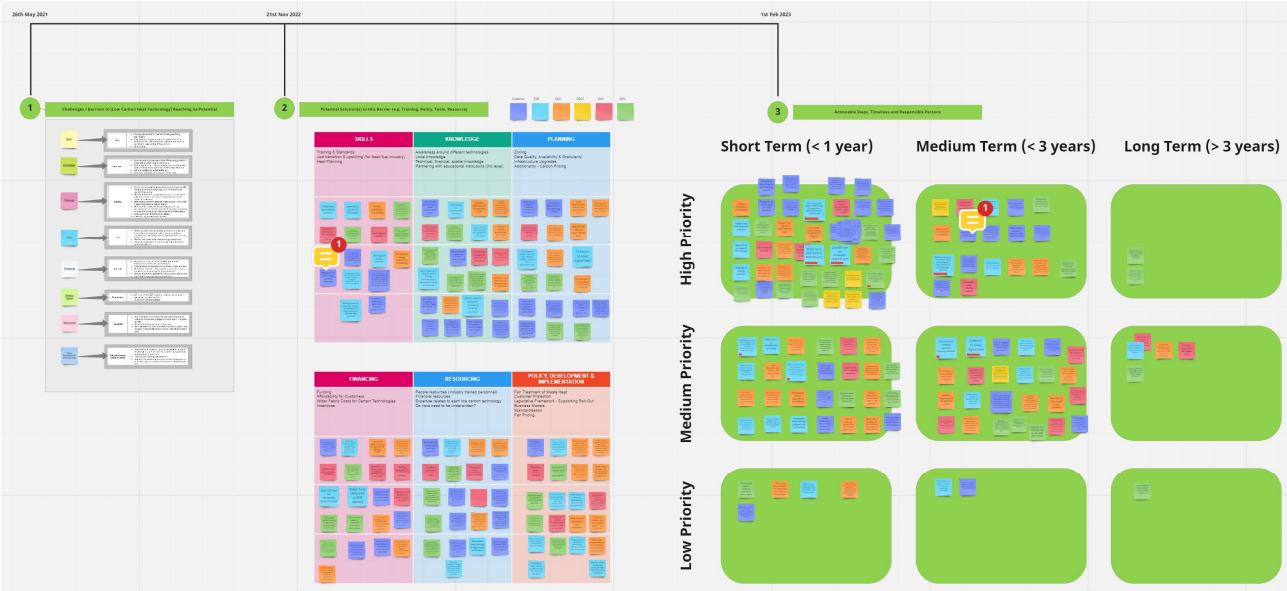

FIGURE 31: SCREENSHOT FROM LOCAL WORKING GROUP ONLINE SESSION ON BARRIER AND ACTION IDENTIFICATION

The outputs of these workshops were then used to form an action list spreadsheet. This spreadsheet lays out the actions in the format shown in Figure 32 (this is also replicated in the Transition Roadmap Actions section of this report). The main information included in this spredsheet includes:

- **Category** – the category in which the action fits (Knowledge & Skills, Resources, etc.)
- **Action** – a brief outline of the action to be taken
- **Completion Date** – Proposed date for when the action needs to be completed
- **Proposed Lead** – The organisation(s) proposed to lead the delivery of this action
- **Proposed Support** – The organisations proposed to support or provide key input into the delivery of this action
- **Supporting Information** – Resources which can be used to inform the delivery of the action e.g. international examples and case studies, further reading, additional context, etc.

Additional columns have also be added to set out indicators for successful implementation (these should be SMART – specific, measurable, achievable, relevant and timebound) or for breaking down actions in smaller, more manageable intermediate steps, these additional columns have not been included in the tables below to allow greater clarity of content. In Dublin it is envisaged that these actions would feed into the wider transition roadmap (for all sectors, not just heat) which would be managed through Dublin's Zero Together project.

Category	Action	Completion Date	Lead	Support	Supporting Information
See list on right hand side	Describe the action to be taken	Date action needs to be completed by	Organisation responsible for delivery of the action	Organisations that need to provide input	Examples/case studies, useful tools, experiments, resources, etc.

- Knowledge & Skills
- Resources (human/financial)
- Regulatory, Policy and Planning
- Technology (readiness to address issues)
- Mindset, Awareness and Engagement
- Governance Structures and Authority
- Legal
- Environmental
- Others?

FIGURE 32: OUTLINE OF THE ACTION LIST BASED ON THE PESTLE ANALYSIS

Transition Roadmap Actions

The action list developed for this transition roadmap is broken into 8 categories:

- Knowledge & skills
- Resources (human & financial)
- Regulatory, Policy & Planning
- Technology
- Mindset, Awareness & Engagement
- Governance Structures & Authority
- Legal
- Environmental

This action list is a living document that will be updated throughout its life as actions get delivered, new actions which address currently unknown barriers are added, and priorities, responsible organisations and dates are refined. It is proposed that the actions below are incorporated into the ongoing management of Dublin's energy transition through the proposed governance process being developed as part of Dublin's Zero Together project.

TABLE 9: REGULATORY, POLICY & PLANNING ACTIONS

Action	Completion Date	Lead	Support	Supporting Information
Develop a transition roadmap for the heat sector in Dublin as part of the Decarb City Pipes 2050 project - Regional strategy for decarbonising heat	2023	Codema	LWG	The final Heat Transition Roadmap for Dublin will be published in Q2 2023 and will be available on the Decarb City Pipes Website
Streamline the planning consent process for heat networks to be considered on a par with other utilities and reflects the role DH can play in tackling CO_2 emissions in the heat sector	2023	DHLGH	DHSG	Further detail on this topic and the options available can be found in the Irish District Energy Associations "District Heating Planning Guidance" report which was produced by MKO. This report is available upon request from IrDEA (email: info@districtenergy.ie)
Update Planning Act to ensure DH developers have the same powers as other utilities to lay pipework. This could potentially be achieved by expanding the definition of "statutory undertaker" to facilitate planning exemptions for this critical infrastructure.	2023	DHLGH	DHSG	Further detail on this topic and the options available can be found in the Irish District Energy Associations "District Heating Planning Guidance" report which was produced by MKO. This report is available upon request from IrDEA (email: info@districtenergy.ie)

Update Part L of the Building Regulations to ensure the fair treatment of waste heat (in line with the RED). DEAP and NEAP shall also include link to online map of existing and planned heat netowrks along with contact details of person/organisation who is responsible for network expansion to raise awareness of this heating option.	2023	DHLGH	SEAI, DECC, Codema, DLAs	Initial method developed but will require some updating over time to include additional heat sources and update intial conservative default figures (Primary Energy Factors & Carbon Factors). Barriers for DH enablement can also be considered such as the lack of data for larger heat pumps that could be used in DH-eneabled/futureproffied group heating schemes. Please see paragraph on district heating on relevant pages of the SEAI website: https://www.seai.ie/home-energy/building-energy-rating-ber/support-for-ber-assessors/technical-support/domestic-ber/space-heating/ Link to the guidance document: https://www.seai.ie/home-energy/building-energy-rating-ber/support-for-ber-assessors/technical-support/domestic-ber/space-heating/Default-district-heating-factors-for-BERs.pdf
Require energy statements to be filled out by large developments to provide information for the purpose of energy planning and to help ensure these are DH enabled. This information shall be maintained in a database	Underway	DCC Planning & DH Teams	Codema	The Dublin City Development Plan 2022 - 2028 States "In order to ensure the future development of District Heating in Dublin City, it will be necessary to ensure that significant new residential and commercial developments, particularly in SDRAs are 'district heating enabled', where feasible, in order to ensure that they are capable of being connected with local or citywide District Heating systems. Where this is not feasible, the proposed energy and heating solution should offer a similarly efficient and low carbon solution". - https://www.dublincity.ie/residential/planning/strategic-planning/dublin-city-development-plan/development-plan-2022-2028
In order for industrial sites which are being developed or expanded a report outlining the potential for waste heat should be submitted with the planning application and in the case where a network is planned/existing in the area heat recovery equipment should be installed	2023	DLA planning teams	Codema	SDCC planning requirement text which enabled waste heat use for the Tallaght Dh project can be found in Section 3.1 of the South Dublin Transition Roadmap - https://www.codema.ie/images/uploads/docs/HeatNet_NWE_Transition_Roadmap_Report_Final_-_Digital.pdf See policy recommendations from D6.3 of SoWhat project for potential further policy supports - https://sowhatproject.eu/wp-content/uploads/2022/11/D6.3-%E2%80%93-Policy-instruments-to-promote-industrial-whc-recovery.pdf

Make renewable heat projects exempt from the Multi-Unit Development Act to allow greater certainty of demand for projects in excess of 3 years	2024	DECC/ Dept of Justice/ DHLGH	IrDEA	The current limit of three years acts as a barrier to heating projects which have larger up-front capital but lower operational costs.
Ensure the role of DH in tackling CO_2 emissions in the heat sector is reflected in the National Planning Framework	2024	DHLGH	DHSG	
Legal requirement for utilities to provide fuel consumption information for their specific location (eircode or coordinates) for heat planning purposes.	2024	CRU, DECC	GNI, ESB, Oil Suppliers	Regulations in Baden-Wurtemberg require utilities (such as gas utilities) and those providing maintenance for heating systems to share their data for energy planning purposes. This law has priority over GDPR. This will enable higher quality heat planning which will be a requirement under the new EED. A similar law also exists in neighbouring province of Hessen - https://www.rv.hessenrecht.hessen.de/bshe/document/jlr-EnGHE2012V2P13 https://www.lea-hessen.de/kommunen/kommunal-waerme-planen/
Introduce more ambitious Renewable Heat Obligation (RHO) for fossil fuel suppliers and ensure DH infrastructure (using high shares of renewable or waste heat) is eligible to earn credits under any proposed RHO. This could also be a framework which Heat Purchase Agreements could use to increase investment in low-carbon heating solutions.	2023	DECC		Further thoughts from Codema on the proposed RHO can be found here - https://www.gov.ie/pdf/?file=https://assets.gov.ie/204794/50fbf420-af6f-4b9e-9a79-2c84209820ad.pdf#page=null This RHO could also act as a framework under which Virtual Heat Purchase Agreements (where a broader set of companies could pay for heat credits) could be facilitated to allow for greater private financing of low-carbon heat solutions.

Assign areas for district heating and cooling (based on viability mapping e.g. from H/C Plan and stakeholder engagement) where large public buildings would be required to connect to DH and other buildings would need to provide proof of why it might not be viable to connect ot DHC as their low-carbon heat supply - Futureproof for connection, link to availability of grants for different technologies to ensure cost parity for customers.	2024	DECC	Codema, DCC, SEAI, IrDEA	Codema's research comparing DH zoning approaches in Scotland, England and Denmark is available upon request and is due to be published on the Codema website in 2023 Dublin City Council have also introduced similar elements in the latest City Development Plan which requires developments of 30 dwellings or 1,000m2 of commercial floor space to produce and energy statement and future-proof for DH connections where feasible. Can also take learnings from the implementation of the UKs 28 DH zoning pilot areas.
Ensure areas identified as suitable for DH (through the energy planning process) are highlighted and supported in Local Development Plans in accordance with regional policy objectives set out in the regional policy objectives from the EMRA	Underway	DLAs	Codema, OPR, EMRA	National and regional suitability maps already exist such as the Codema DH viability and heat source maps https://codema-dev.github.io/posts/, the IrDEA Heat Atlas https://districtenergy.ie/heat-atlas/ , and the SEAI DH candidate area map https://gis.seai.ie/districtheating/
Initiate a DH zoning pilot in the Dublin area to learn by doing. Can also take learnings from 28 UK pilot zoning schemes.	Underway	DCC	Codema	As part of the Decarb City Pipes project a policy experiment on zoning for DH was considered. Some of the learnings from this process are now incorporated in the City Development where new larger developments across the city are required to consider DH as a heating solution and future proof for DH where this is feasible.
Develop a national stance on green hydrogen that outlines this should only be used for hard-to-abate uses where lower cost low-carbon alternatives do not already exist such as use a feedstock for industry, aviation etc.	2023	DECC		Green Hydrogen should be used for high-exergy applications or as a feed stock for industry where other sustainable alternatives do not exist. Therefore, it is not foreseen that green hydrogen will play a role in the provision of space heating or hot water preparation. Further thoughts on this can be found in Codema submission to Ireland Hydrogen Strategy Consultation - https://www.codema.ie/images/uploads/docs/Codema_Submission_on_Hydrogen_Strategy_Consultation.pdf

Lower taxes on electricity used for supplying low-carbon renewable and waste heat	2024	DECC		The large differential between electricity and gas prices can be an impediment to the adoption of technologies such as heat pumps. Information on the current "Spark Gap", in countries across Europe can be found in Section 3.3 this report by the IEA HPT TCP Annex 48 - https://heatpumpingtechnologies.org/publications/final-report-annex-48-industrial-heat-pumps-second-phase/ Fairer levies on electricity can help reduce this gap and make heat pump more cost competitive. This report by the Regulatory Assistance Project "Levelling the Playing Field " report https://www.raponline.org/wp-content/uploads/2022/07/Taxes-and-levies-final-2022-july-18.pdf
Review level of consensus and legal requirements to allow buildings with multiple privately-owned dwellings to deliver whole-building heat solutions or connect to DH networks	2024	DECC/Dept of Justice/ DHLGH		In some European countries, only a majority (more than 50%) consensus of tenants is required to adopt a new whole-building heat solution and in others this % is much higher. Need to better understand the thresholds required in Ireland and review if these are found to be prohibitively high thresholds.
Review the heat loss threshold required to secure grants for heat pumps - look at potential for increasing the allowable heat loss index to allow more homes to be eligible for support but without exceeding limits that would result in poor heat pump performance. It should also be allowed that measured heat loss figures from a heat loss survey of the building be used to prove the buildings heat loss for grant eligibility purposes.	2024	SEAI		Further study needs to be done on determining a suitable heat loss indicator for heat pump adoption. This refined HLI threshold should also be related to the type of emitters used in the building and the associated flow temperature in these emitters. DEAP is not a robust means of calculating real world heat loss. This is due to a number of factors, such as models not capturing the as-built details of the building due to data gaps (undocumented changes to the building etc.). Having a grant system that is based on this logic is similarly not robust and could lead to unnecessary and expensive retrofitting works being carried without a real need. To this end, real world measurement of heat loss should be an acceptable alternative to the HLI calculated through the DEAP software. This type of heat loss measurement is carried out by companies such Veritherm https://veritherm.co.uk/testing/

Ensure customers are protected. Particularly ensure that residential customer currently on gas-based communal schemes are not subject to commercial gas price increases as these systems are often confused with Efficient DH networks	2023	CRU	EPA on licencing?	The Heat Trust (https://www.heattrust.org/the-scheme) is a voluntary regulatory standard for DH in the UK and is not being subsumed into Ofgem (the utility regulator in the UK) the learning from this process could inform similar development of the heat network regulatory process in Ireland. The regulator may also act as the licencing agency for developing and operating heat networks in the country.
Require local authorities which have 45,000 inhabitant or more to produce heat plans in line with the latest EU Energy Efficiency Directive.	2024	DECC		Final threshold is to be determined as part of the EU trialogue by end of Q2 2030 and is likely to be between 35,000 and 50,000. IN either case this would make heat planning a requirement for at least 30 of the 31 local authorities in the country (Leitrim being to only exception).
Phase-down plan for gas networks which are currently used to provide space heating and hot water. This shall include specific closure deadlines for fossil fuel infrastructure for specific geographical locations e.g. gas boilers will be banned in 5 years and gas network will be turned off 10 years after DH starts to be developed in a given zone.	2024	GNI	CRU, DECC	Winterthur law example where a shut of date for gas to flow through the gas network has been set for 2032 and gas boilers have been banned as of 2020 - https://www.zh.ch/de/politik-staat/gesetze-beschluesse/gesetzessammlung/zhlex-ls/erlass-730_1-1983_06_19-1986_07_01-118.html?search=energiegesetz ACER report on Future Regulation of Natural Gas Networks https://www.acer.europa.eu/sites/default/files/documents/Media/News/Documents/Future%20Regulation%20of%20Natural%20Gas%20Networks%20-%20Final%20Report%20DNV.pdf The Future of Gas (EASAC) https://easac.eu/fileadmin/user_upload/EASAC_Future_of_Gas_Web.pdf
Ensure that remaining gas customers are protected from gas network capacity charge increases when the gas infrastructure is being phased down until they get to transition to low carbon technologies.	2026	CRU	GNI, DECC	Gas phase down should be coordinated with the introduction of alternative heating technologies. This could be one of the roles of the Integrated Heat Planning Team discussed under the "Governance Structures and Authority" actions.

TABLE 10: RESOURCES ACTIONS

Action	Completion Date	Lead	Support	Supporting Information
Establish a dedicated fund at the required scale for the delivery of DH networks.	2023	DECC/ DH Programme Office	DPER, NTMA, Delivery Unit	The long-term source of funding for this could come from carbon tax funds, the proposed renewable obligation, or other sources. Aside from delivering networks this will also provide a market signal to attract private sector involvement and spark investment in training. Current funding methods such as the CAF have limits which can curtail the development of larger networks.
Resource a DH delivery unit to support the roll out of DH networks - support (technical, financial, legal) to local authorities, community groups or other organisations looking to develop networks	2023	DECC	SEAI, Codema	
Provide resources to allow public sector organisations (LAs, CRU, DECC, etc.) to hire dedicated full-time staff to facilitate the roll-out of DH (e.g. heat planners, project coordinators, regulator, licencing, etc.)	Ongoing	DECC/ Delivery Unit	Relevant public sector organisations	It is important that these staff members have heat decarbonisation as a key element of their role and that this is supported at all levels of management. The report developed by Energy Cities on the Human Capacity in Local Governments: The Bottleneck of the Transition provides indicative numbers for Local Authorities as well as innovative ideas on how to attract talent and foster peer-to-peer learning between Local Authorities https://energy-cities.eu/wp-content/uploads/2022/05/EnergyCities21_PolicyPaper_CapacityNeeds_EN_FINAL-2.pdf
Produce a private investor pack for DH to provide background information on the investment opportunity for Dh in Dublin -	2024	Codema	DH Investors	This short document could include information on supporting policy and targets, example returns, source of other part-funding, risk & mitigation. The findings from the Dublin H/C Plan can help inform this piece of work. The UK Heat Networks Overview brochure provides a good example of a clear and engaging format for such a document https://heatnetwork.zone/documents/BEIS_Heat%20Networks_The_UK%20market.pdf

Develop a national level insurance scheme to underwrite some of the risks associated with waste heat use which are not naturally the responsibility of the waste heat owner or the DH company.	2024	DECC	DPER	An example of such a situation would be if waste heat owner goes out of business. This may be too big a burden for smaller DH companies to shoulder and therefore be a barrier to development of a project. Similar schemes exist in relation to de-risking drilling geothermal projects in the Netherlands. - https://www.rvo.nl/sites/default/files/2020/04/Handleiding-risicos-dekken-voor-aardwarmte-2020.pdf
Ensure that building owners are supported through grants to install heat substations in their building in the same way that heat pumps are supported.	2024	SEAI		

TABLE 11: KNOWLEDGE & SKILLS ACTIONS

Action	Completion Date	Lead	Support	Supporting Information
Engage with educational institutions and existing private sector organisations (ESCo, consultancies, etc.) to deliver training and certification to build indigenous capacity to deliver the heat networks required in areas such as DH pipe installation, heat pump system design, etc.	Ongoing	Codema	SEAI, Engineers Ireland, 3rd Level Institutions, ETB, FETAC, HETAC, DFHERIS, QQI	Engagement with local Education and Training Boards, Manufacturers, Technical Universities, and Professional bodies such as Engineers Ireland has already begun to help deliver local skilled workers to facilitate the roll out of DH. Further engagement is required to deliver formal training in areas where skills are currently lacking. The skills gaps for DH in Ireland are expected to be similar to those in other countries where DH currently has a lower market penetration like the UK. The following documents outline some of these skill shortages. Heat Networks Skills Analysis for Scotland - https://energysavingtrust.org.uk/wp-content/uploads/2020/10/Heat-Network-Skills-Analysis-for-Scotland.pdf Energy Savings Trust Skills Initiative Report - https://energysavingtrust.org.uk/wp-content/uploads/2020/10/Heat-Network-Skills-Initiative-PDF-1.pdf BEIS Heat Network Skills Review 2020 - https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/919521/heat-network-skills-review.pdf Initial steps have been taken by Codema to introduce the area of DH

				to relevant bodies with the development of the "Fundamental of District Heating" course which Codema delivers on behalf of Engineers Ireland which draws on the experience of Codema in developing heat networks in Ireland - https://www.engineersireland.ie/Events/event/7887
Develop an online platform where highly skilled designers and installers can share their knowledge and provide ongoing support for those encountering challenges on the ground as they arise	2025	DH Delivery Unit	IrDEA	This can provide additional support when real world situations are encountered that cannot easily be accounted for in more formal training courses.
Raise awareness and provide additional training for those workers with complimentary skills currently working in the fossil fuel industry or other related industries such as facility management & ESCo's to enable them to work on the development, operation and maintenance of DH networks.	2024	DH Delivery Unit	Codema, IrDEA, SEAI	
Provide financing to small businesses looking to upskill workers to install less familiar low-carbon installations (heat pumps, DH pipework & substations, lower temp secondary heating systems and controls). This would allow workers to upskill without significant drop off in earnings and without putting the financial burden of attending the training and the initial lower productivity on the small business owner when learning a new skillset. This is important in a highly competitive labour market. Alternatively, this could be delivered by means of a tax credit for workers who are upskilling.	2024	DH Programme Office/DECC/DPER/DFHERIS/SEAI/DH Delivery Unit		This would look to soften to impact of potentially lower earning potential when someone transitions to a new sector and initially has a period of lower productivity due to being less familiar.

Hold heat planning workshops to upskill planners, etc. in the area of heat planning to ensure high level of quality for such plans for each LA area - Share tolls re heat sources available etc.	Ongoing	Codema	DLAs	Codema heat & energy planning workshops and other European workshops such as Hotmaps, Act!on Heat etc. This will become more important as the requirement for Municipalities (of greater than 45,000 inhabitants) to carry out heat planning under the proposed EU Energy Efficiency Directive. This would cover all but one municipality in Ireland.
Develop a guide for developing feasibility studies for DH projects including supporting tools and templates in order to develop a pipeline to investment decision stage. This will include standardised installation cost information, carbon pricing, etc.	2023	Codema /SEAI	Relevant Stakeholder groups	Codema are currently deploying this guidance on behalf of SEAI and in conjunction with key stakeholder groups - further information on this can be found by contacting Codema or visiting the project page on the Codema projects page - https://www.codema.ie/projects
Wider dissemination of key design principles and highlight standardised efficient designs for M&E installation in buildings (DH connections, heat pumps, etc.)	2024	IrDEA/ Codema		The overarching design principles are currently discussed in the Fundamentals of District Heating course - https://www.engineersireland.ie/Events/event/7887 (currently delivered by Codema on behalf of Engineers Ireland and with discussions to deliver similar content in conjunction with local ETBs) and in CIBSE CP1 Training course. https://www.cibse.org/training/search-courses/heat-networks-code-of-practice-cp1-full-course Other useful guidance include the BEIS Het Network optimisation videos (covers topics such as managing water flows, water quality, flow and return temperatures, complexity, insulation and plant room efficiency) https://www.gov.uk/government/publications/heat-networks-optimisation-guidance-to-help-operators-improve-performance/heat-network-optimisation-guidance-videos , Bristol & Plymouth Guides for Technical Designers of Heat Network connections https://www.plymouth.gov.uk/sites/default/files/ConnectingToThePlymouthHeatNetworkPart2.pdf. Tools like Hysopt can also be used to optimise hydronic system designs and controls for specific systems.
Networks that are being developed should be contractually obliged to make time (a defined	2023	DH Delivery Unit	IrDEA	

number days) available to local tradespeople etc. to learn by seeing in order to help build local capacity for delivering networks and help those transitioning to gain familiarity with DH procedures				
A minimum requirement in terms of local workers should be considered to stimulate the local supply chain and create local wealth where possible.	2026			
Incentivise contractors from the EU to come to Ireland to share knowledge. This can be supported through the development of ambitious targets & Investor/contractor information sharing and engaging with Embassies or directly with multinational companies.	2023	DECC/ IrDEA	Euroheat & Power, IDA, Embassies, International ESCo's & contractors	
Use output led approach to the procurement of DH projects in order to leverage knowledge and experience from external organisations	Ongoing	DH Developers	Codema	This approach was used for the Tallaght DH network and can help engage/leverage international experience to a greater degree. Further details on this approach are available from Codema (email: codema@codema.ie)
Support new DH regulator by supplying specialist DH knowledge and experience to ensure safe, affordable and reliable heat supply.	Ongoing	District heating steering group/ IrDEA		This is key to ensuring high quality of service and building confidence with potential heat customers
Government grant to be made available for those looking to complete registered courses relevant to building capacity in the DH sector	2024	DFHERIS	DPER	UK example - Training providers: register to offer the Heat Training Grant for heat networks - https://www.gov.uk/government/publications/training-providers-how-to-offer-the-heat-training-grant-for-heat-networks
Ensure best practice examples or projects and approaches from around Europe are shared with Irish stakeholders through sharing reports and holding knowledge sharing sessions - Decarb, Celsius, DBDH, EH&P, IEA TCP, etc.	Ongoing	Codema /SEAI/ DH Delivery Unit	DH Developers	An example of this is the HeatNet NWE project which looked to promote the development of 4th Generation DH in 6 countries across north-west Europe. The resources developed as part of this project can be found on the following online platform - https://guidetodistrictheating.eu/ Other useful platforms include the Celsius Toolbox

				https://celsiuscity.eu/category/toolbox/

TABLE 12: TECHNOLOGY-SPECIFIC ACTIONS

Action	Completion Date	Lead	Support	Supporting Information
Heat recovery equipment for the capture of waste heat to be eligible for support under the SSRH or similar support scheme such as CAF	2023	SEAI, DECC		
Consider inclusion of the recommendations outlined in the "From Data Centres to District Heating & Cooling: Boosting waste heat recovery to support decarbonisation" paper at a national level	2023	DECC	Codema/ EH&P	A link to this paper produced by Euroheat & Power with input from Codema and other representatives from both the DH and data centre industries is available here https://www.codema.ie/media/news/codema-supports-new-recommendation-paper-from-data-centres-to-district-heat
Support the development of deep geothermal heat source to provide indigenous, renewable and secure heat supply for DH and industrial applications. This can be done through provision of funding for exploration/research (e.g. seismic surveys & exploratory boreholes) to better quantify the resource and ensure this information is available for DH project development.	2023	DECC/ GSI/DPER	Codema/ SEAI	

TABLE 13: MINDSET, AWARENESS & ENGAGEMENT ACTIONS

Action	Completion Date	Lead	Support	Supporting Information
Effectively communicate the details of how to apply for funding under the proposed heat network fund described above.	2023	DECC/ DH delivery unit	IrDEA members	

Develop material to highlight pathways for those currently working to fossil fuel industry (many of whom have complimentary skills - pipe installs, metering & billing, asset management, etc.) to transition into DH	2024	Codema	GNI, GSI, etc.	Those who work in the fossil fuel industry may have concerns about the future of their industry and the impact it is having on emissions and the resulting climate change. These people possess many transferrable skills that can be utilised to build capacity within the low-carbon sector. However, pathways for transitioning people from the fossil fuel to the green sector are not well known or communicated.
Raise awareness of Thermal Energy Storage for providing services to the electricity grid in the form of grid balancing/demand flexibility, frequency response, etc.	2024	Codema	Energy Storage Ireland, ESB, Eirgrid, CRU, NNLC	Codema electricity storage consultation submission (Jan 2023) - https://www.codema.ie/images/uploads/docs/Codema_Submission_on_Developing_an_Electricity_Storage_Policy_Framework_for_Ireland_-_Final.pdf Further study has also been carried out by Codema into the potential contribution of thermal storage to delivering a more resilient Irish energy system as part of the Poolbeg RDD Project. This study focused on curtailment mitigation of renewable electricity generators such as offshore wind and found that thermal storage can provide energy storage at approx. 1% of the cost of battery storage and requiring less than 10% of the land. Further details on this project can be found here - https://www.codema.ie/projects/local-projects/integration-of-heat-electricity-and-transport-use-of-curtailed-renewable-en EU Commission Recommendation Paper on Energy Storage states that "in particular large thermal storage in district heating systems, can provide flexibility and balancing services to the electricity grid and therefore provides a cost-saving system integration solution by absorbing variable renewable electricity production (e.g. wind and solar energy)". - https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32023H0320(01)

Early engagement with the public to raise awareness of heat networks - will help avoid misinformation, highlight the comparative benefits of DH, liaise with waste heat owners (industrial sites etc.) - share case studies, publish prices with a comparison with alternatives, host tours of DH networks, facilitate sessions with other regions in Europe to share knowledge	2023	DECC	IrDEA, SEAI, Codema	Ongoing engagement in European project and forums is hugely important for knowledge sharing. The Decarb City Pipes project itself is a great example of this. This also helps promote best practice as outlined in the "Knowledge & Skills" actions.
Conduct a citizen engagement survey in relation to district heating. This will help gauge likely connection rates and key concerns of potential customers to ensure these are addressed.	2023	ESRI/ Codema /SEAI		See example from Communication Works "Winning the Hearts and Minds" report - https://communicationworks.eu/eng/wp-content/uploads/sites/2/2017/08/UK_District_Heating_Communication_Works_2017-1.pdf
Maintain an online map of both existing and planned heat networks including contact details of person/organisation responsible for each network's expansion (a link to this information should be provided in any DEAP or NEAP software)	2024	Codema		Cities like London already have a map of both planned and existing heat networks along with heat sources https://maps.london.gov.uk/heatmap Dublin has heat source https://codema-dev.github.io/map/heat-source-map/ and DH viability maps https://codema-dev.github.io/map/district-heating-viability-map-v2/ but as networks are rolled out it is important that the existing and proposed networks are also mapped so potential customers/stakeholders can see if they have a network nearby
Investigate the potential for certifying sites as a waste heat supplier to support corporate social responsibility objectives or comply with waste heat utilisation policy. Site provide data on waste resource and make their heat available for DH when developed.	2024	DH Delivery Unit / DECC	Local Authorities	Such a certification scheme could be a waste heat version of something like Origin Green (used in the food industry). As part of this WH owners would provide data to help characterise their resource and sign a MoU to make this heat available if a DH network were to be developed in the area. This scheme could also act as eligibility criteria for LAs to reduce rates for companies which sign up to this initiative. As part of the EED Data Centres of 100kW or more will be required (March 2024) to publish the proportion of their waste heat being utilised. Could this be expanded to other waste heat owners such as waste water treatment plants etc.

Develop tool to identify likely suitable business model for DLAs and other organisation who may be interested in developing DH networks	2023	Codema	DLAs	A methodology for assessing this is being explored as part of the District Heating Feasibility Study Guide being developed by Codema on behalf of SEAI
Develop a best practice guide for customer service in heat networks including minimum customer protection standards.	2025	CRU	DH Companies, Other utilities	This could include discussion on items like: Complaints department structuring (assigned rep who contacts the various depts on behalf of customer rather than customer being kept on hold), rewards & incentives for desirable customer behaviour and/or engagement, etc.
DH networks that are developed should host regular tours of their installations to act as demo sites for customers, policy makers etc. to have real life sites to visit	2023	DH developers	DH Programme Office, Dh Delivery Unit, Codema, HeatWorks, IrDEA, SEAI	Rewards & incentives for good customer behaviour e.g. sets up direct debit, turns down thermostat (could gamify against neighbours)
Engage with Sustainable Energy Communities and local business organisations to raise awareness about DH potential in their area & how to progress potential community projects	2023	Codema	SEAI, LA	Directly asking customer what they would like to see e.g. various future heat source options - pay more for certain tech but might have more price security etc.
Publish heat prices publicly with comparisons to alternative heating solutions to help with potential misunderstandings on the difference between heat price and fuel price.	2024	CRU	DH developers	Heat Trust comparison tool https://www.heattrust.org/heat-cost-comparator Published Danish heat prices - https://forsyningstilsynet.dk/tal-fakta/priser/varmepriser The Tallaght DH network will also be publicly publishing its heat price to improve transparency, engagement and trust. These prices will be published in the HeatWorks website https://heatworks.ie/
For rental properties where split incentives between landlords and tenants are an issue. Rental prices inclusive of estimated heating costs from the building BER/EPC should be required to be published when advertising the premises for rent.	2024	DHLGH	SEAI	SEAI behavioural insights unit report on behavioural barriers to retrofitting - https://www.seai.ie/news-and-media/behavioural-barriers-to-r/

Map and facilitate stakeholder (supply and demand side) engagement and particularly engagement with local authorities to test approaches, gather feedback and refine outputs at a more local level.	Ongoing	Codema, Delivery Unit		GIS maps produced for Tallaght and Blanchardstown. Certain data available from Codema upon request.

TABLE 14: GOVERNANCE STRUCTURES & AUTHORITY ACTIONS

Action	Completion Date	Lead	Support	Supporting Information
Set up a national delivery unit which will be responsible for providing technical and financial support to those looking to develop networks and ensure high standards of design, installation, feasibility etc.	2023	DECC		Thoughts on what such a unit could look like including key roles and responsibilities are available from Codema & SEAI
Create an integrated heat planning team for the heat transition including all relevant utilities (gas, electric, DH).	2023	Codema	Decarb City Pipes LWG	This will also help with ensuring roll-out of low-carbon heating and the phase down of fossil fuel infrastructure is aligned i.e. low-carbon commissioned before FF supply is turned off. This should also help with the flow of data and knowledge and help avoid each utility thinking in their own silo and potentially missing integration opportunities and cost-efficient solutions that come from holistic planning. This may also allow the process of securing an electricity grid connection for heat pumps and electrode boilers to be more streamlined which is currently one of the biggest risks for delays. This could be a potential ongoing role for the LWG (perhaps in conjunction with the Zero Together team. Trench sharing and coordination of installation works can also be optimised as part of an expanded group which could include highways teams, broadband installers etc. as well as the ability to make strategic decisions on technology pathways such as biomethane or the role (if any) for existing gas network infrastructure. An effective structure is already in place in cities like Vienna. Greater detail on this structure is available from Codema.

Need to implement a system of measurement and verification to track targets and contribution to CO_2 emission reductions.	2024	DH Delivery Unit	DH developers	Where the ongoing operation of the network is being carried out by private ESCo's this sharing of data should be included as a requirement at contract/procurement stage

TABLE 15: LEGAL & ENVIRONMENTAL ACTIONS

Action	Completion Date	Lead	Support	Supporting Information
Develop template contracts to reduce the legal burden of developing contracts for DH projects from scratch	Ongoing	Codema	SEAI, Philip Lee	An Irish DH contract template has been developed by Philip Lee solicitors in conjunction with Codema and SDCC based on the contracts developed as part of the Tallaght DH network Examples from other jurisdictions include the SOMS templates (UK) https://tp-heatnetworks.org/heat-contract-templates/ Examples from the R-ACES project https://r-aces.eu/tools/legal-decision-support-tool/
Provide guidance on developing contracts for DH networks need to include important performance criteria such as the carbon content of the heat produced and the level of service provided to customers (e.g. limit the number and duration of outages)	2024	DH Delivery Unit	CRU	
Develop mechanisms through which 3rd parties can provide renewable or waste heat to the DH networks	2027	DH Delivery Unit	CRU	
Consider the potential to take advantage of economies of scale by performing an Environmental Assessment and Appropriate Assessment for all areas identified as suitable for DH if required	2024	DHLGH, EPA	SEAI	

DECARB CITY PIPES 2050

Transition Roadmap City of Munich

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 893509

Transition Roadmap of Munich

Introduction

Space and water heating requirements account for a total of about 34 percent of the entire energy consumed in Germany. In private households, heating and water heating are even responsible for around 90 percent of total energy consumption. In addition, the demand for cooling and air conditioning is rising continuously. In Munich, heat demand from residential and non-residential buildings is even higher, covering about 48 percent of total final energy consumption.

At the same time, fossil fuels currently still dominate as energy carriers in the heat sector, both in Germany as a whole and in Munich. Not surprisingly, greenhouse gas (GHG) emissions of the heating and cooling (H/C) sector make up slightly more than a third of energy-based GHG emissions in Munich. Consequently, the success of the energy transition and the transition to climate-neutrality is decisively dependent on more energy-efficient buildings, economic use of energy and future climate-friendly GHG-free energy generation and management.

There is a long history of climate protection policies in Munich. In 2010, so-called Integrated Action Programs for Climate Protection in Munich (IHKM) have first been designed. Climate protection strategies and measures in the H/C-sector have since then always played an important role. Recently, climate change issues have even become much more prominent and visible in Munich.

Munich's municipal utility company Stadtwerke München (SWM) is a key player in the energy and heating transition. SWM supplies Munich with energy (electricity, natural gas, district heating/cooling), fresh drinking water, mobility and advanced telecommunication services. Moreover, there are city-owned housing companies which play an important part in providing affordable housing and transforming the building stock to account for the requirements of climate neutrality.

The next section describes in some more detail the current situation with respect to climate protection and the role of the H/C-sector as well as overall goals of the City of Munich and SWM. Then, a more detailed outlook of Munich’s H/C-sector for the future is provided. Based on that, key levers and strategies for the transition are explained and a selection of local instruments are mentioned. As Munich is currently revising major part of its strategy for the H/C-sector the final section provides an outlook on current discussions.

Status quo and goals for 2035 and beyond

In line with the Paris climate protection agreement of 2015, the City of Munich declared to become a climate-neutral city by 2035 and brought forward its previous goal from 2050 to 2035 (defined as 0.3t CO2e per inhabitant). The city administration and companies closely attached to the city administration have to reach the goal of climate neutrality by 2030 already. With the city council resolution of 18 December 2019[20] where these goals have been passed, Munich has also declared a climate emergency. The city administration was asked to develop an action plan that defines a path to achieve climate neutrality for the entire city by 2035 and for the city administration by 2030.

For this purpose, the Department of Climate and Environment commissioned a study that reviewed previous scenario calculations and developed proposals for such a comprehensive action plan ("Climate-neutral Munich 2035"). The department then presented two basic city council decisions (Grundsatzbeschlüsse). The first one in June 2021 outlines the importance of the neighbourhood approach (see below) and proposes some mostly institutional changes in city climate governance (e.g. establishment of a municipal climate ordinance, a climate council with various stakeholders, a separate climate budget, a climate appraisal of council resolutions). The second one in January 2022 then presented the above-mentioned action plan and the necessary financial outlay for climate protection measures highly prioritized and in need of financing from the city's climate budget (mostly for the period 2021 to 2025).

SWM makes a significant contribution to Munich’s energy transition with its own goals and by actively supporting the goals of the city of Munich. With respect to district heating and cooling, SWM is the only supplier in the designated district heating and cooling area (900-kilometer long; outside some local grids from other suppliers exist). In the year 2012, SWM announced the District Heating Vision: SWM will cover Munich’s entire district heating requirements on a CO_2-neutral basis. Tapping geothermal energy is a key component of this vision. In addition, the expansion of green district cooling is supposed to replace individual air conditioning systems. Energy consumption for cooling shall be reduced by using groundwater and city streams. Furthermore, from 2025, SWM intends to produce as much green electricity in its own plants as the entire municipality of Munich requires.

In 2020, a study on the future of Munich's heating sector was commissioned by SWM in cooperation with the city of Munich (so-called "heat study"). The study develops a long-term concept to reach Munich's climate goals, outlines transition paths with respective transition costs and proposes instruments and measures based on current barriers on the way to climate neutrality. The study was also used as a basis for the broader study ("Climate-neutral Munich 2035") mentioned above.

At the moment, there is still a long way to go to reach climate neutrality. The Department of Climate and Environmental Protection regularly publishes greenhouse gas emission (GHG) inventories with a two-year time lag which are final energy-based and cover both scope 1

[20] https://risi.muenchen.de/risi/dokument/v/5822571

and scope 2 emissions. Figure 33 shows the emission trend and the breakdown of GHGs by sectors. While emissions have decreased considerably by 46% relative to 1990, progress has obviously been too slow within the last five years to easily achieve city goals.

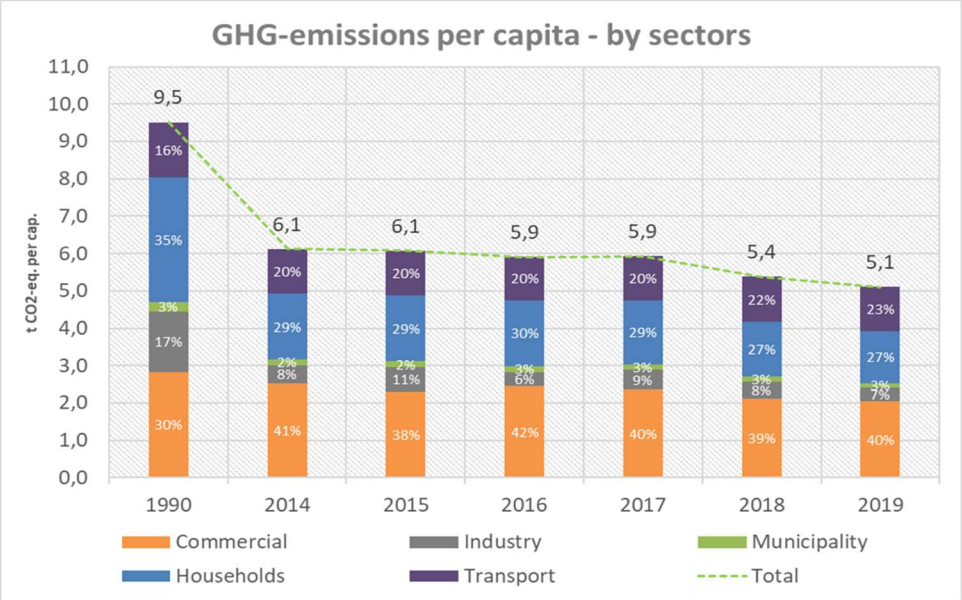

FIGURE 33: SOURCE: MUNICIPAL GHG-MONITORING, HTTPS://RISI.MUENCHEN.DE/RISI/SITZUNGSVORLAGE/DETAIL/7205164

Scenario calculations of the studies mentioned above suggest that, using ambitious but still realistic assumptions, greenhouse gas emissions can be further reduced by almost 70% until 2035 (Figure 34). The achievement of Munich's climate goals will then very likely not be completed by 2035 unless the city resorts to further measures outside the city boundary and monetary compensation schemes. The main reason for this result is the relatively slow transformation of long-lived infrastructure (like building refurbishment, expansion of the public transportation network and the district heating network, remodelling of energy generation plants). Yet, in the 2040s, climate neutrality can be reached depending on the speed of realising necessary changes in Munich and the development of favourable framework conditions.

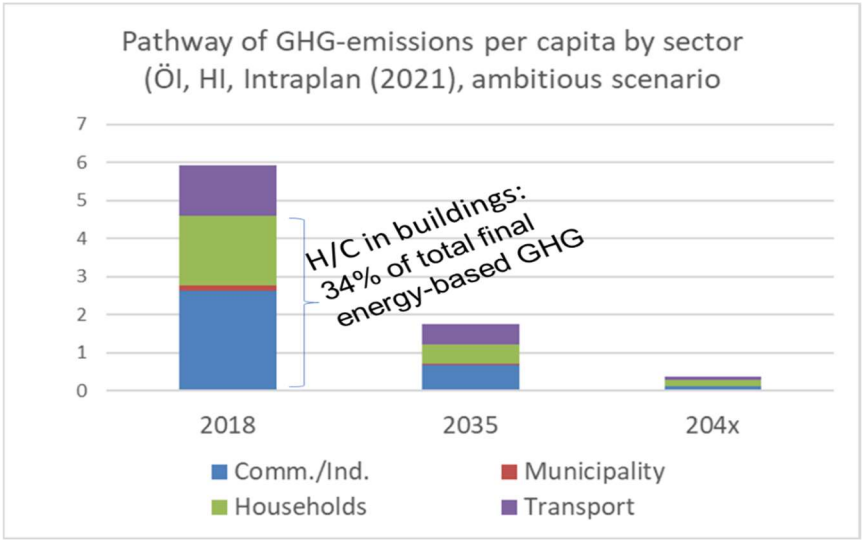

FIGURE 34: SOURCE: ÖKO-INSTITUT ET AL. (2022)

Outlook H/C-sector

Currently (2018), fossil fuels still dominate as energy carriers in the heat sector: of total heat energy consumption, 53% originates from natural gas, 35% from district heating (predominantly still based on natural gas and coal in cogeneration plants), 9% from heating oil, and with 3% from other sources. According to the heat study mentioned above, Munich will see a considerable shift in the way heat is provided (Figure 35) and a change in the composition of energy sources (Figure 36).

In particular, there will likely be higher shares of district heating (about 50% in 2035, about 70% in 2050) in final energy consumption and, in parallel, the decarbonization of district heating will unfold. This is mainly possible via very favourable conditions for deep geothermal energy: Up to two thirds of energy generation for district heating in 2035 will originate from this energy source, with an installed capacity in 2035 of up to 510 MWth (MW of thermal power) (including heat pumps for reheating at generation sites). Currently, only 80 MWth is based on deep geothermal energy.

In parallel to the rise of geothermal energy in base load and partly mid-load district heating, the burning of coal in one of the CHP plants will cease by the late 2020s. Gas-fired CHP and heat plants will be partly refurbished and continue to operate until 2035. (Note: The study was finished before the war in Ukraine and the resulting energy crisis). By 2035, all existing CHP plants (and also heat plants) are assumed to switch to hydrogen as energy carrier and will only operate when national electricity demand cannot be covered by renewable energy. Consequently, CHP plants will operate much less in 2035 given the expected costs of hydrogen at this time. Their share will only rise in later years.

To cover the remaining mid- and peak load in district heating, largescale electric heat pumps at generation sites will play an important role. Also, additional renewable heating capacity for peak load is likely to be necessary (based on biomass or power to heat). Overall, the transformation of the generation plants for district heating will lead to a much higher reliance on local renewable energy sources than today (70% in 2035, 56% in 2050).

While Munich has generally quite favourable conditions for district heating in terms of heat density, suitable buildings etc., district heating and the expansion of the district heating grid is not a suitable option in all parts of the city (Figure 35). In these other areas, oil and gas boilers will have to be replaced mainly by individual heat pumps and/or local heat grids. According to scenarios in the heat study, these decentralised solutions make up for about 15% of final energy consumption in 2035 and up to 30% in 2050.

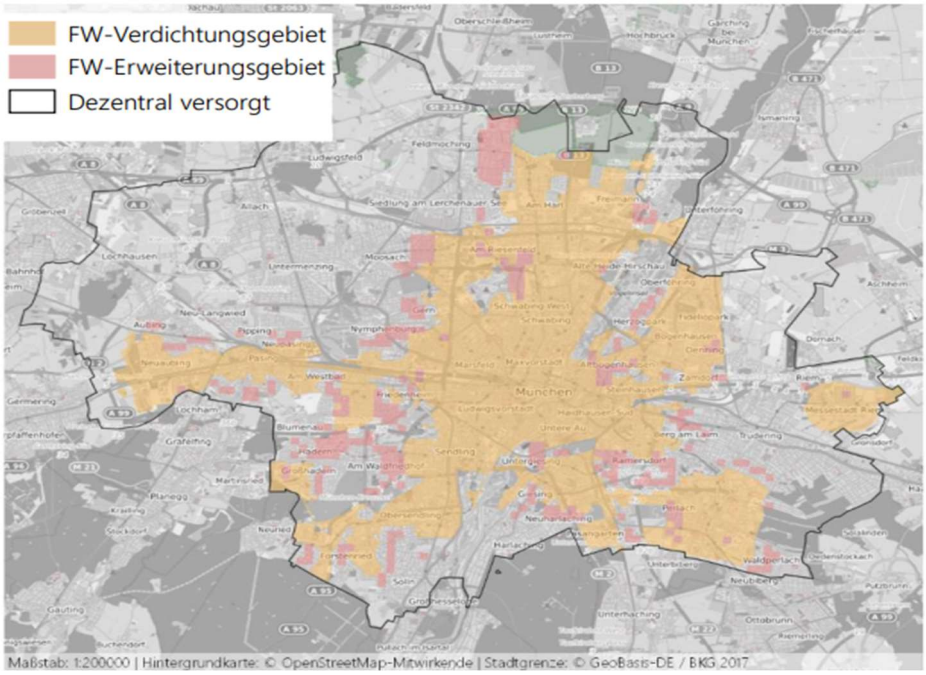

FIGURE 35: EXISTING AND EXPANDED DH AREA, ACC. TO ÖKO-INSTITUT AND FFE (2021)

Fortunately, Munich has also favourable conditions for near-surface geothermal energy in combination with groundwater heat pumps in many (but not all) parts of the city. Moreover, these areas are also mostly outside the currently designated district heating area. The main favourable factors for this technology are relatively high groundwater temperatures, the relatively low depth to the water table (less than 20 m), the high groundwater thickness and the high permeability of underground gravel. Apart from groundwater heat, pumps there is an additional potential for geothermal heat collectors in combination with heat pumps (using brine). They typically require more space than groundwater-based systems. Current analyses show that up to 60% of the current heat demand can technically be met by groundwater heat pumps or geothermal heat collectors without negative mutual interactions between wells.

Apart from the above-mentioned heat pumps, air-based heat pumps are also often suitable replacement options for oil and gas boilers. This is particularly the case for less densely populated areas of the city, where the spatial requirements can be met more easily or noise disturbances may be less prevalent. Moreover air-based heat pumps are currently perceived as more attractive given their relatively lower investment cost. The expansion of these more inefficient heat pumps may result in a greater need for expansion of the electricity grids.

In addition to heat pumps, there will likely be other decentralised heating sources for a climate-neutral heating sector. Solar thermal energy (mainly for water heating or in small local heat grids), waste heat (e.g. from industry, bakeries, data centres) and biomass (e.g. in some areas without groundwater potential) have to be mentioned. Also, thermal and chemical storage will play an increasing role given limits to renewable electricity use for heat pumps. However, the importance of these latter energy sources is likely to be limited from a city-wide perspective.

In parallel to changes on the supply side, it is crucial that energy consumption in buildings is further reduced. After all, there are technical and economic limits in supplying large amounts of green heat in a big city like Munich. At the same time, the potential to increase

the energy efficiency of the building stock is considerable: almost 60% of the residential buildings in Munich's have been built before the first federal heat ordinance in 1978. Another 20% has been built before 1995. Compared to current standards for new buildings, these buildings are fairly inefficient and most of them have not or only partly been refurbished afterwards. Given this potential and favourable framework conditions (i.a. rising energy prices, federal funds) the heat study assumes an increase of both the rate and depth of renovation. The rate of renovation will increase from slightly over 1% p.a. to up to 2.5% in the period 2036 - 2050, the depth of renovation will increase from a level of about 70 kWh/m2 (KfW 85) in single and double family houses and about 57 kWh/m^2 (KfW 70) in apartment buildings up to about 45 kWh/m^2 (KfW 55) in the former and about 32 kWh/m^2 (KfW 40) in the later buildings. Only in the district heating area and in historic buildings the depth of renovation will be somewhat lower. As a result, 25% (61%) of all buildings can be renovated until 2035 (2050) and final energy consumption will decrease by 16% (2035) and 35% (2050), respectively.

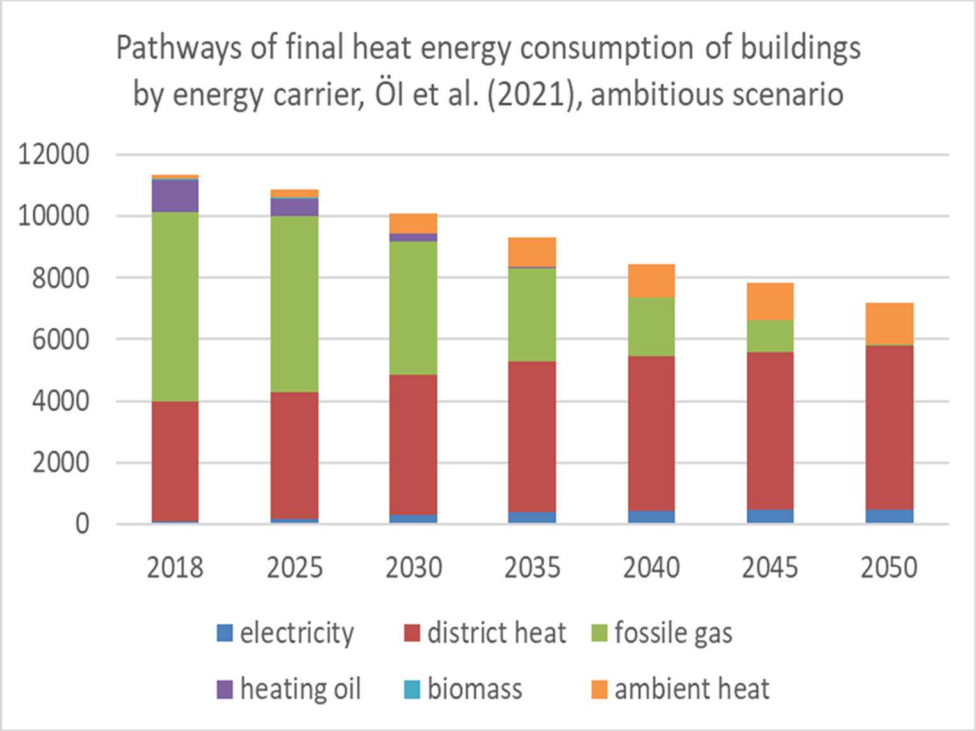

FIGURE 36: SOURCE: ÖKO-INSTITUT AND FFE (2021): KLIMANEUTRALE WÄRME MÜNCHEN 2035, SZENARIO FOKUS FERNWÄRME

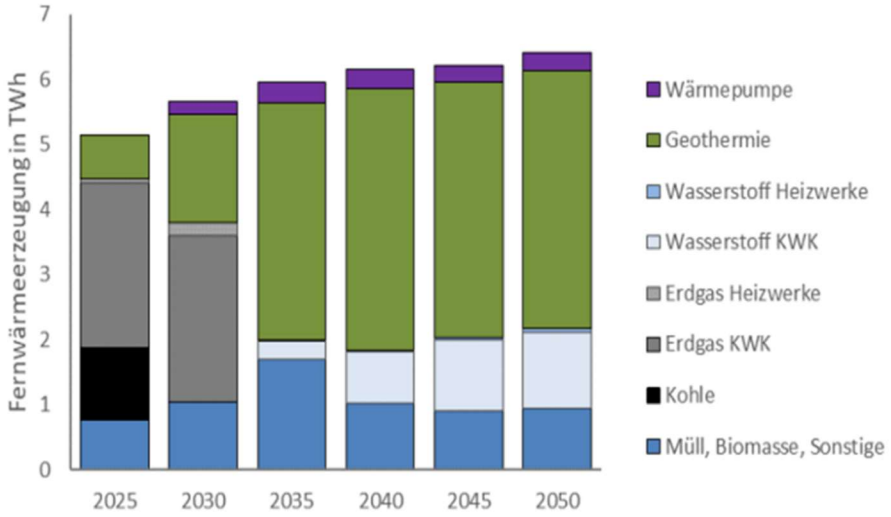

FIGURE 37: PATHWAYS OF EXPANDING AND DECARBONISING DISTRICT HEAT PRODUCTION, SOURCE: SWM, BASED ON ÖKO-INSTITUT AND FFE (2021)

The changes in the level and composition of CO_2-emissions resulting from centralised and decentralised heating are shown in Figure 38 for the two climate scenarios analysed in the heat study. While emissions decrease considerably until 2035, there are likely to be left-over emissions of 900 to 950,000 CO_2 (thereof 18% for incinerating waste that can likely not be avoided or recycled). The largest share of remaining emissions results from decentralized gas boilers where quick phase-out is challenging. Also, despite the rising share of heat pumps, the emission factor for electricity is only declining step-by-step. Emissions from district heating can be reduced substantially until 2035 given the expansion of geothermal energy and the switch from natural gas to hydrogen in remaining CHP and heat plants. Depending on further developments regarding the legal, technical and economic framework conditions, it will be seen whether the switch from natural gas to hydrogen by 2035 is possible and can take place on the scale shown (see Figure 37).

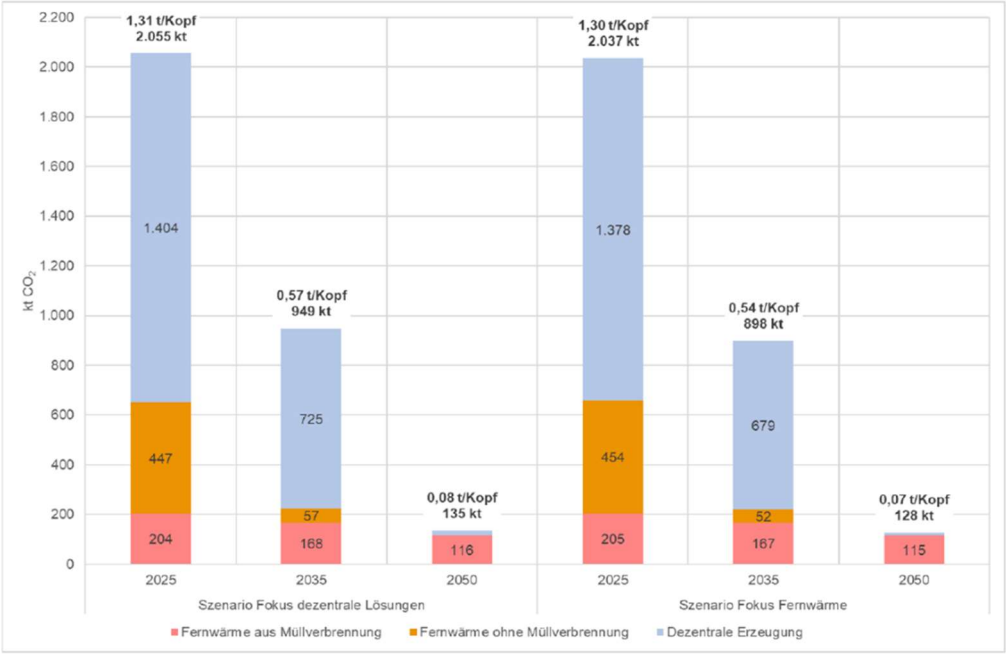

FIGURE 38: CO_2-EMISSIONS FROM HEATING IN THE SCENARIOS OF ÖKO-INSTITUT AND FFE (2021)

Key levers and strategies

a) Strategic and city-wide H/C planning

In 2022, the City of Munich and SWM started redesigning and reorienting strategic and citywide H/C-planning. Originally, the city had its own energy planning system, the so-called energy use plan, with only limited involvement of the local utility and limited integration of their energy and building data and analysis tools. Following the closer cooperation between the city and SWM during the development of the heat study and a change of responsibilities within the city administration (i.a. establishment of the Department of Climate and Environment), SWM decided to open up some of their data and tools (so-called Model Munich) to selected persons of the city for a better alignment of H/C-planning in Munich. As a result, H/C-planning now relies on more detailed and valid data sources as well as analysis tools that are easy to use and update. The main responsibility for H/C-planning still lies within the city administration as H/C-planning can be considered a service of general interest, but cooperation with SWM remains close.

Overall, H/C-planning serves to inform building owners, energy suppliers and other interested stakeholders about suitable options on the way to a climate-neutral H/C-sector. This includes energy supply technologies and heat sources, energy infrastructure and energy demand and use. At the same time, planning helps to better coordinate activities of various stakeholders and the respective interests and strategies in the H/C-sector. As a result, planning and investments of these stakeholders can be realized on a more reliable basis. Moreover, interacting and communicating with stakeholders on a regular basis ideally creates more trust and more support for Munich's ambitious journey towards climate neutrality. Finally, planning is meant to stimulate measures for implementation. The integrated neighbourhood approach is a key strategy in this regard (see below).

b) Transformation of district heating

H/C-planning serves to determine areas within the city that are suitable for either grid-bound or decentralized heat and cold supply. As already mentioned, district heating is a key pillar of grid-bound energy supply. The main responsibility for the development of future district heating lies within SWM as sole operator in Munich. Currently, SWM develops the so-called transformation plan for district heating which is embedded in city-wide H/C-planning.

The transformation plan describes the remodelling and/or expansion of an existing heat grid and system to climate-neutrality until 2045. It serves as a basis for funding of investments of both heat grids and heat production or storage installations. Similarly, building owners aiming to rely on district heating on their way to climate neutrality can only fully benefit from federal funding for retrofitting buildings if there is a valid transformation plan. The transformation plan needs to be approved by the federal level. Yet, the contents are discussed and agreed upon at the local level between SWM and the City of Munich (agreement on climate neutral district heating, link to H/C-planning).

The transformation of district heating includes the following main building blocks:

1) Grid Densification

There are still a lot of buildings in the district heating network area which are not connected to the district heating grid. Connection rates need to be increased along with change of restrictive federal tenant regulations (currently under review).

2) Grid Optimisation

A considerable share of the district heating network is still based on steam with very high temperatures and low efficiency. Major parts of this network need to be converted to hot water and temperatures need to be adapted. The optimization of the grid infrastructure needs to be closely aligned with changes on the generation side (e.g. changes of temperatures, adaptation of customer units, potential use of secondary grids etc.).

3) Grid Extension

While grid densification in the existing district heating network has generally a higher priority than grid extension, the heat study has already designated areas outside the district heating network area where expected long-term revenues of district heating are likely to exceed the cost of infrastructure provision and supply of district heating. In the currently developed transformation plan, these areas are considered more closely.

4) Generation

A fundamental shift will be necessary on the generation side where large CHP and heat plants using fossil fuels have predominated so far (see outlook on H/C-sector above). By contrast, the backbone of future district heating will be based on new generation units spread across the wider Munich Metropolitan area, mainly using deep geothermal energy.

A key element is the connection of plants located in favourable regions south of Munich to the city-wide district heating grid. For this purpose, cooperation agreements with neighbouring municipalities and new business models will be necessary. Put differently, SWM can only realize less than a third of the technical geothermal potential in the wider Munich area without such agreements.

Of course, and in addition to three existing plant locations, a number of locations for new geothermal plants are also planned or considered within the city borders. In addition to each geothermal unit, largescale heat pumps are also planned. Moreover, there are first ideas for high-temperature underground thermal storage units at current or new plant sites. They basically help to mitigate the temporal mismatch between availability and demand for thermal energy.

Despite the dominating future role of geothermal energy - and expected persistence of waste heat from incineration in district heating - other energy carriers will likely play an additional role. The use of hydrogen, biomass and additional waste heat (incl. wastewater) are currently considered more closely.

5) District cooling

District cooling is another key element of SWM’s commitment to climate protection policies. The natural eco-coldness of groundwater and urban streams is tapped to drastically reduce the power consumption in the cooling and air conditioning process. By comparison with

individually generated cooling, especially in terms of conventional domestic air conditioning systems, up to a 70 percent of the electricity requirements can be saved.

c) Integrated neighbourhood approach (“Quartiersansatz”)

A considered ‘neighbourhood’ is composed of several locally adjacent buildings including public infrastructure. It is smaller than an administrative city district and constitutes an informal level for city planning and development.

The city council has decided that the integrated neighbourhood approach is a key strategy on the way to a climate-neutral and resilient Munich. The approach will focus on existing buildings and on areas which are not formally designated refurbishment areas according to the German Building Code.

The neighbourhood approach allows to realize synergies and/or to save costs compared to either a building-by-building approach or a city-wide-only approach. Compared to the building-by-building approach, advantages include the possibility to combine refurbishment activities or to integrate renewable energies or green infrastructure at larger scale, to intelligently couple the electricity and the heat market and to realize critical investments levels. Compared to the city-wide approach, it is easier, for example, to inform and activate citizens at the neighbourhood level, coordinate and align the various interests and to test new innovative approaches or technologies.

The integrated neighbourhood approach follows two main avenues: The first is based on the development of integrated neighbourhood concepts, which are promoted by the German public bank KfW. This concept provides a more detailed analysis of a selected neighbourhood (status quo (energy use, major energy carriers, infrastructure, main actors etc.), potentials (e.g. building refurbishment, change of heat source, greening, mobility concept), costs, transition path and monitoring and accounting). It also proposes and prioritizes suitable measures for the transition and integrates local stakeholders in the process. The close cooperation with local stakeholders (e.g. house owners) aims to ensure the subsequent implementation of the concepts.

Based on the concept, the management of the refurbishment (Sanierungsmanagement) can also be promoted by KfW. This involves the implementation of the concept at the neighbourhood level (incl. stakeholder activation, networking, coordination, monitoring etc.).

At the moment, there are about eight pilot integrated neighbourhood concepts (at various stages). It is planned to learn from these initial experiences and scale the approach in the coming years, so that about 20 concepts can be launched each year from 2025 onwards.

The second avenue focuses in particular on areas dominated by single and two-family houses which are more homogenous and less complex and do not necessarily benefit from a separate neighbourhood concept. In these areas the city of Munich office individual, free and targeted energy counselling by independent experts and develops accompanying campaigns. The first such counselling campaign in the Western part of Munich has started in 2022 and turned out to be a great success. For the coming years, it is planned to have about two to four such campaigns each year. Moreover, the city offers information, counselling and training on building refurbishment, energy and new living and building concepts also through a citywide centre (Bauzentrum).

Both integrated neighbourhood concepts and targeted energy counselling benefit from the energy and heat planning mentioned above. In particular, the heat planning tools allow to preselect and prioritize areas in the city that are suitable for (integrated) neighbourhood concepts and/or targeted energy counselling campaigns. They also offer valuable data and information for more detailed and fine-grained calculations and scenarios at the neighbourhood or building level.

d) Set up an energy / renovation agency

A team of experts from various departments of the city administration is basically responsible for preparing and monitoring activities at the neighbourhood level and for aligning them with goals and demands of the city council. However, much of the day-to-day work at the neighbourhood level cannot be managed by them, especially at the implementation stage of the concepts and given the plan to scale the neighbourhood approach. Therefore, the setup of a new energy and renovation agency is necessary. Such an agency would be more agile and flexible than the city administration, but still be controlled and supervised by the city and supported by the city's climate budget. Currently, city officials examine whether the Munich Society for City Renewal (MGS) - currently still part of one of the municipal housing associations - can be turned into such an agency.

e) Set up of new business fields at SWM

SWM is currently developing a new business field "decentralized heating". It is composed of two main product lines: M-Heat pump and M-Local heat. The former is oriented towards individual solutions for single buildings and includes both air- and groundwater-based heat pumps. SWM aims to develop standardized and all-inclusive service packages (selection of heat pump, installation, support in securing funding, electricity tariff, service and maintenance etc.). Given increasing competition in the individual heat pump market SWM is also aiming to quickly reach a sufficient market share.

The latter (M-Local heat) is aiming to set up local heat grids based on near-surface geothermal energy and other renewable energy sources both for new and existing buildings. While successful projects for new buildings already exist, viable solutions for existing buildings are more challenging.

f) Adaptation of electricity and gas infrastructure

SWM has recently made the strategic decisions to continuously phase-out the sale of natural gas and to not provide further connections to the gas grid whenever compatible with national energy law. By contrast, customers will be offered an alternative heat supply, typically either district heating or decentralized renewable heat (see above). The future of the current gas distribution grid and the exact phase-out strategy (timing, region-by-region approach) is currently still under discussion. However, the heat study and the climate neutrality study have shown that maintaining the entire gas distribution grid to provide hydrogen to former natural gas customers is not a viable option given the cost and competing uses for hydrogen. Therefore, only the supply of hydrogen directly to CHP and heat plants is currently considered a potential option. In addition, high-pressure gas distribution lines to supply hydrogen to selected industry customers in and around the city are probably maintained or even newly built.

The roll-out of heat pumps (and electric vehicles) has also important implications for the electricity sector. In particular, local electricity grids will face peak loads which are about twice as high as today. Together with the University of Augsburg and the Technical University of Munich, SWM is currently examining in more detail the repercussions on the local electricity sector (e.g. expansion of transformation substations, change of electric equipment etc.). Interestingly, the need to adapt is likely to vary substantially within the city, depending particularly on the heat load, the heat pump technology and load management.

Local instruments

The complexity of decarbonising the City of Munich - with its countless buildings, owners and inhabitants as well as the limited space and the limited financial and human resources - requires thoughtful planning. In addition, the path to climate neutrality is strongly influenced by market signals, citizen engagement and acceptance, and federal and state legislation. Ideally then, the right measures can be taken at the right time.

To this end, the following table provides an overview on tools to achieve the climate targets, focussing on tools currently available to the City of Munich. These instruments are constantly being further developed so that they support the implementation of the strategies and levers mentioned above.

TABLE 16: MAIN MUNICIPAL INSTRUMENTS FOR THE TRANSITION TO CLIMATE-NEUTRAL H/C

Brief description	Type	Main related strategies / levers	Status
Adaptation of planning to account for the spatial needs of the heating transition (plants, installations, grids), incl. streamlining of permitting	Planning and legal	a), b), c), e), f)	Used, increasingly important
Information on spatial requirements of the H/C transition (needs, availability), integration of concerns of the H/C transition in other (informal) plans / concepts	Information and planning	a), b), c), (e), f)	Currently establ. (City Development Plan 2040, land utilisation plan)
Provisions on RE-use and building standards related to land-use planning (particularly new buildings, buildings on city-owned ground)	Planning and legal	a), b), c), e)	Used, increasingly important
Provisions on energy supply and building standards in case of sale / lease of publicly-owned ground	Planning and legal	a), b), c), e)	Used
Notifications / permits for activities regarding near-surface geothermal energy (water rights)	Planning and legal	a), e)	Used, increasingly important
Licences for use of public ground in grid-bound energy supply	Planning and legal	b), e), f)	Used

Application of distance requirements acc. to the state building code to take account of the H/C transition (e.g. heat pumps)	Planning and legal	c), e)	Currently under review
Provisions on energy supply and/or building standards in urban development contracts	Planning and legal		Not yet used
Designation of urban renovation areas and redevelopment statutes acc. to federal building law	Planning and legal, financial	a), c)	Used, limited city-wide effect
City-wide municipal heat ordinance	Planning and legal	a), b), c), e), f)	Currently under review
Mandatory connection and use provisions for heat grids	Planning and legal	b), e)	Currently under review
Fossil fuel burning restrictions acc. to federal building law	Planning and legal	a), b), e), f)	Currently under review
Enforcement of federal and state law related to the H/C transition (building, energy, ambient pollution etc.)	Enforcement	c), e)	Obligatory
Provision of information for integrated neighbourhood concepts, energy counselling campaigns and energy concepts	Information and planning	c), d)	Used, increasingly important
Provision of information and planning tools for near-surface geothermal energy	Information and planning	c), d), e)	Used, increasingly important
Using city-owned building as nucleus in the H/C transition	Information and planning	c)	In preparation
Provision of geo-based information on the H/C transition (e.g. solar potential)	Information and planning	a)	Continuously improved
Energy counselling for citizens by city-owned building centre (Bauzentrum) and the Munich Society of City Renewal (MGS)	Information and planning	c)	On-going
Events and conferences related to the H/C transition by city-owned building centre (Bauzentrum)	Information and planning	c), e)	On-going

TABLE 17:

Brief description	Type	Main related strategies / levers	Status
Legal oversight and controlling of the new energy and renovation agency	Management of municipal companies	d)	In preparation
Co-operation with the new energy and renovation agency at the neighbourhood level	Management of municipal companies	c), d)	On-going
Complementary municipal funding of new energy and renovation agency at the neighbourhood level	Financial	d)	In preparation
Influence on statutes, guidelines, strategies of municipal companies relevant for the H/C-transition (i.e. SWM, city-owned housing companies)	Management of municipal companies	all	Used, increasingly important
Strategic agreement between the City of Munich and SWM on the transition to climate-neutral district heating	Management of municipal companies	b)	In preparation
Strategic agreement between the City of Munich, SWM and neighbouring communities on the H/C-transition (i.e. reservoir management deep geothermal energy)	Cooperation between municipalities	b), (f)	In preparation
Own municipal funding programme for climate-neutral buildings (energetic refurbishment, new buildings, H/C-installations, energy counseling, PV; individuals, housing associations)	Financial	a), c), e)	Used, further adaptation in line with H/C-planning, increasingly important
Reduction of energy demand and decarbonisation of city-owned buildings	Financial	(a), own strategy	On-going
Temporary compensation of transition costs to climate-neutral heating	Financial, social	Social/ housing	Currently under review
Involvement of city-external experts in the H/C transition	engagement and participation	a)	On-going
Public citizen involvement and campaigns (“Re:think Munich”) at the neighbourhood level	engagement and participation	a), c)	On-going
Round Table “Skilled Personnel”: education, re-education, training	Training and education	All	Recently started
Round Table “Skilled Personnel”: Attracting new personnel	Labour market	All	Recently started

The Road Ahead

In principle, Munich is well prepared to embark on an ambitious journey to climate neutrality, both in the H/C-sector as well as in other sectors. However, the outcomes in terms of emission levels, share of renewable energy or final energy consumed are not solely controlled by the city or by SWM.

There is now likely to be a more markable impact of federal- (and also EU- and state) level legislation on local energy policies than in the past. Currently, a new version of the Energy Building Law is discussed and prepared at the federal level, basically obliging building owners to use at least 65% renewable energy in case of change of boilers and to phase out fossil fuels in the sector by 2045 at the latest. With the enactment of this law the federal level would have a fairly deep impact on decisions about heating technology of individual building owners and a markable influence on planning and instrument choice at local level (incl. on what is legally allowed and proportionate at this level). In addition, other critical programmes, regulations and laws (e.g. on obligatory municipal heat planning, on the promotion of district heating or on the future use of energy infrastructures) have either been passed or are currently discussed. They indicate that the federal level is taking the H/C transition more seriously. Yet, depending on the contents of these federal activities, certain local actions may be stimulated and/or restrained.

In addition, the H/C transition is critically dependent on other factors which can only be influenced by the city to some extent. Notably, implementing widespread energy refurbishment and change of heating technologies relies on planners, energy counsellors and manufacturers. Moreover, the political, social and market acceptance of the H/C transition is very important, but not very well known and not easy to be sustained.

Therefore, designing a transition roadmap at the local level is not a one-time exercise. It needs to be revised and adapted based on changing circumstances and continuous learning.

Literature

Öko-Institut und FfE (2021): Abschlussbericht zum Projekt: Klimaneutrale Wärme München 2035, Ermittlung der Möglichkeiten zur Umsetzung von Lösungspfaden für eine klimaneutrale Wärmeversorgung in der Landeshauptstadt München, Forschungsgesellschaft für Energiewirtschaft mbH & Öko-Institut e.V., München & Freiburg.

Landeshauptstadt München (2022): Grundsatzbeschluss II Klimaneutrales München 2035 und klimaneutrale Stadtverwaltung 2030: Von der Vision zur Aktion, Sitzungsvorlage 20-26/ V 05040. In https://risi.muenchen.de/risi/sitzungsvorlage/detail/6635836, München.

Öko-Institut et al. (2022): Fachgutachten Klimaneutralität München 2035, im Auftrag des Referats für Klima- und Umweltschutz der Landeshauptstadt München, Öko-Institut e.V., HIC Hamburg Institut Consulting GmbH and Intraplan Consult GmbH, Freiburg / Hamburg / München.

DECARB CITY PIPES 2050

Transition Roadmap City of Rotterdam

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Transition Roadmap of Rotterdam

Introduction

“By 2050, Rotterdam wants to be climate neutral: we no longer want to contribute to climate change. Because the CO_2 emissions and other greenhouse gases are a major cause of climate change, we want to reduce them significantly. As a city in the delta, the consequences for Rotterdam cannot be foreseen if we don’t act. One way to reduce emissions is to switch to alternatives to natural gas. This is also useful because in the future, much less natural gas will be produced in Groningen. In addition, we are preparing ourselves for the consequences of climate change, such as flooding and heat stress.”

The Heat Transition is a task from the national Climate Agreement.

On the basis of the Paris Agreement, European agreements and the Dutch Climate Act, the government has committed itself to reducing the Netherlands’ CO_2 emissions over time. In the National Climate Agreement, companies, organisations and governments have indicated how they intend to reduce their emissions by 49% by 2030 compared to the reference year 1990. In this Climate Agreement, it was agreed that municipalities will take the lead in the heat transition of the built environment. To this end, every municipality is drawing up a Heat Transition Strategy. In this vision, they inform the government which neighbourhoods and homes have the potential to become natural gas-free by 2030, or to prepare for this.

The municipality is a suitable director of the heat transition.

In Rotterdam, we believe it’s important to manage the heat transition locally. After all, this transition will bring about major changes for Citizens of Rotterdam, not only in the outdoor areas and below ground, but also in people’s homes. It is therefore essential that residents and property owners understand the importance of the transition and that there is support for it. The heat transition requires good coordination and alignment between many parties. This is the only way to achieve the most sustainable and reliable heat alternative at the lowest possible social costs. Municipalities are therefore the appropriate governmental level to take responsibility for this.

The heat transition also offers opportunities for other solutions.

In Rotterdam there are more challenges besides the energy and heat transition. Climate adaptation, greening and housing construction all require a place in our increasingly limited outdoor space.

Building owners also face many challenges, such as repairing foundations, removing asbestos and overdue maintenance. This raises the question of how we can make and maintain buildings which are more liveable and future-proof. And: how do we keep the solutions affordable and achievable for everyone?

The implementation of the heat transition offers opportunities for smart combinations, 'linking opportunities', with solutions for other challenges. In the district-oriented approach, we are therefore linking up as much as possible with other challenges in a district, such as reducing flooding, improving the quality of life, tackling poverty and strengthening the local economy. We are also looking for linking opportunities in spatial solutions, construction works in outdoor area and planned renovations by large property owners. In doing so, we will provide tailor-made solutions as much as possible, because every district is unique. This also saves costs and reduces disruption. Together, we are not only making Rotterdam natural gas-free, but we are also working on a better future for all citizens of Rotterdam!

The Goal – Our Heating and Cooling Plan "WHAT-Map"

Currently, Rotterdam has 263,000 natural gas connections, which are mainly used for cooking, heating and hot running water. We must therefore start on time to ensure that all buildings in the city are natural gas-free before 2050. We will do this in phases, so that the city remains accessible during the heat transition, and we can make optimal use of resources and people. To be able to make sufficient headway towards 2050, a number of components are required. These will enable us to heat buildings with a clean heat alternative:

- The available technologies to provide a building with heat
- The necessary infrastructure and spatial possibilities
- The availability and development of sustainable heat sources
- The degree of energy saving required to save CO_2 and to make buildings suitable for a heat alternative.

The challenge of making Rotterdam natural gas free in numbers:

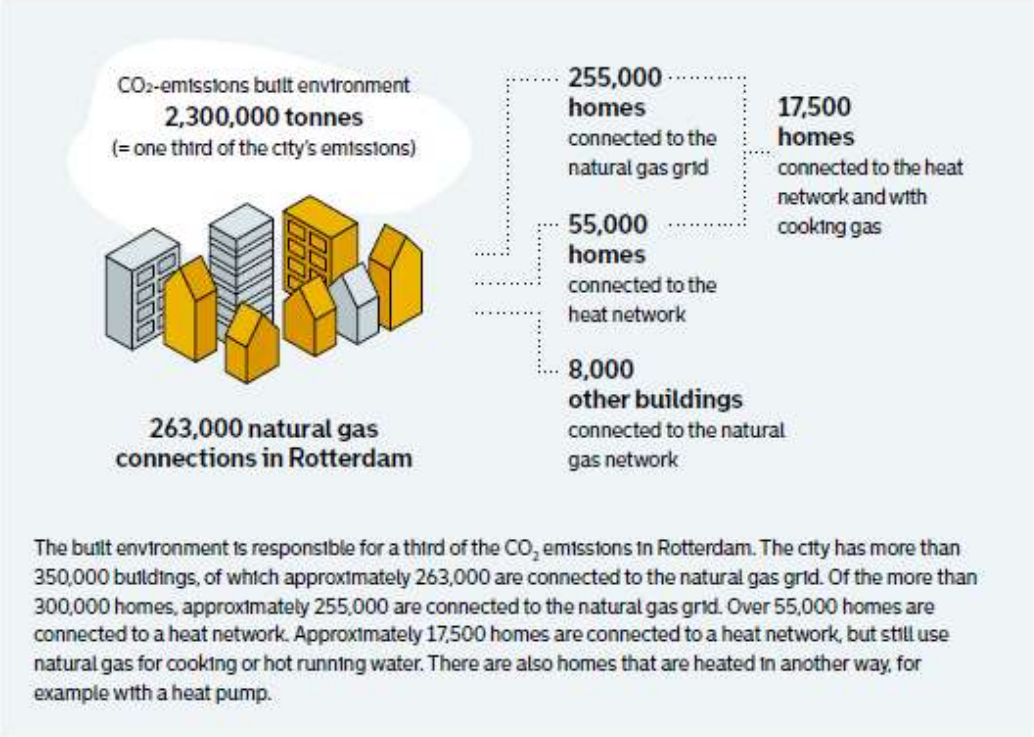


FIGURE 39: CHALLENGE OF MAKING ROTTERDAM NATURAL GAS FREE IN NUMBERS

Each alternative to natural gas requires different adjustments and investments. This has consequences for the efforts that users and heat and electricity suppliers must make. We aim to achieve the most suitable and affordable solution for all parties.

We are introducing the WHAT map, which will be used to determine the best heat alternative for each district.

An affordable heat alternative at the lowest social costs

We have calculated the cheapest alternative to natural gas for the existing buildings in Rotterdam. The results of this calculation are shown on the WHAT map. This map was published for the first time in 2018 and was improved in 2021 in line with the latest insights and technologies. The WHAT map shows the most affordable alternative to natural gas for each district. It also shows how much more advantageous this option is compared to the second choice in terms of a percentage.

To arrive at this WHAT map, we studied various alternatives to natural gas. These included variations of a collective heat network at low, medium or high temperature, as well as fully-electric heating per house, with heat pumps that extract heat from the air or soil. We added up the costs and benefits for each option, regardless of who pays the costs and who receives the benefits: investments in infrastructure, modifications to the home and energy costs. This allowed us to compare the social costs of different alternatives. Our goal was not to get a picture of the actual specific costs of implementation, but rather an indication. The actual costs are tailored and depend on the specific characteristics of the buildings.

By choosing the cheapest solution, we will be less reliant on national and local subsidies. However, this does not alter the fact that connecting to sustainable heat will not necessarily

be affordable for many citizens of Rotterdam. For this reason, we are also investing in funding energy-saving and home improvement measures to reduce energy consumption.

To determine which alternative to natural gas is a no-regret, we have compared the costs of various options. We paid particular attention to the difference in costs between the alternatives: the greater the difference, the more likely it is that a solution really is the cheapest in practice. We have also taken into account the composition and setup of a district: connecting a district with many gallery flats/multi-family houses is cheaper than connecting a district with many detached houses. Finally, there are always buildings that require custom solutions, such as monuments and properties with specific characteristics, like churches, theatres, museums and houseboats. For these buildings, it is difficult to determine the best alternative in advance.

The WHAT map presents the preferred alternative to natural gas at district level. We do not prescribe the alternative heat source. The WHAT map gives an indication of the relationship between the costs at district level of the various solutions and thus the likelihood of installing a collective heat system. Building owners are free to choose another alternative.

The WHAT map is an important tool for the municipality, as it provides insight into its role in various situations. The heat alternative largely determines the coordination and cost allocation that will be needed. In districts where a collective heat supply is to be installed, the municipality will most probably take the lead. In areas where building owners can independently realise an alternative, the municipality wishes to support this. An interactive version of the WHAT map[21] will be made available on the website Duurzaam010.nl[22].

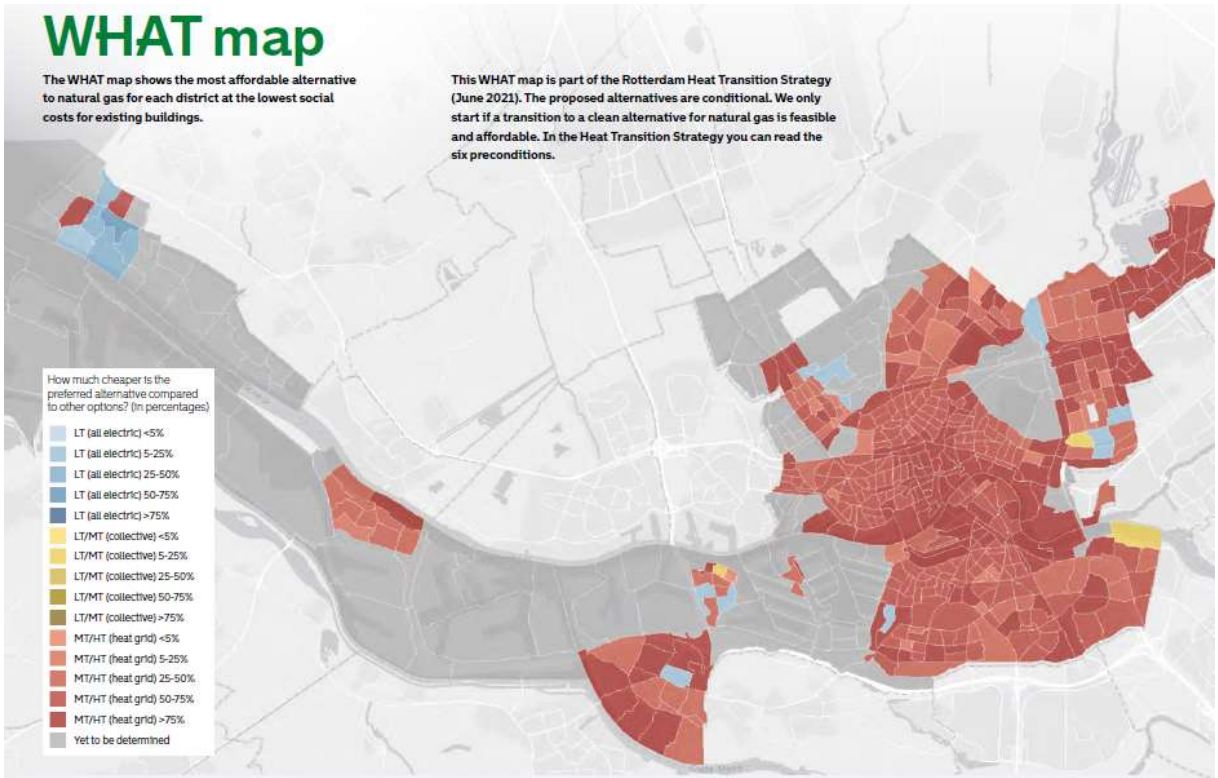


FIGURE 40: ROTTERDAM'S WHAT-MAP

21 https://rotterdam.maps.arcgis.com/apps/webappviewer/index.html?id=6e37b7b6c0df407f881edb007e819803

22 https://duurzaam010.nl/

A heat network is the cheapest option

As the WHAT map indicates, in large parts of the city, collective heating solutions are an attractive alternative to natural gas in terms of affordability for residents, landlords and businesses. A medium or high temperature heat network is the cheapest alternative for the majority of Rotterdam's districts. The initial analysis by the Netherlands Environmental Assessment Agency and the Openingsbod (opening offer) from grid operator Stedin confirm this.

This in itself is not surprising. In an urban environment, collective systems are often the socially cheapest alternative to natural gas. About one-fifth of the buildings in Rotterdam are already connected to district heating; we have been using heat networks since the 1950s. Further economies of scale mean that costs are lower and also more fairly distributed. Heat would then be distributed to homes via a heat network. The advantage of a heat network is also that it is suitable for using other sources of heat in the future, making it a no-regret investment.

Another sustainable alternative to natural gas is electric heating (all-electric). This is an individual solution per house, which is relatively expensive. Most existing houses in Rotterdam must be heavily insulated for this type of heating, making this solution, on balance, often more expensive.

Energy saving

We are entering a (transition) period in which it will be a challenge to ensure the availability of sufficient clean, reliable and affordable energy for existing buildings in time so that we can stop using natural gas by 2050. It is also necessary to reduce the use of natural gas and make better use of available heat. New buildings are already being built without a natural gas supply. By reducing the demand for heat – think of (stimulating) energy-saving and home-improvement measures – and thus: reducing natural gas consumption, we directly contribute to the CO_2 target.

Energy-efficiency and home improvement

We are encouraging businesses, homeowners, tenants and landlords to be energy efficient in various ways. We do this by means of national regulations and offering subsidies and loans from the central government ("Warmtefonds") and the municipality, energy advice through VVE010 and information through our own channels (including the website Duurzaam010.nl). With energy coaches to improve heating behaviour, offering advice and help with small energy-saving measures and the purchase of energy-efficient appliances, we are taking various steps in Rotterdam to promote cost-effective energy saving in an easy-to-implement manner.

Insulation

The greatest gains can be achieved by ensuring that buildings have the right level of insulation to match the heat supply. Insulation lowers energy costs and reduces the pressure on the available sustainable heat sources. It is therefore an effective way of balancing the supply and demand for clean energy in 2050. The WHAT map therefore takes into account both investments in the heat system and in insulation. It may mean that buildings need extra insulation to be able to use of a certain alternative to natural gas, such as low-temperature heating.

This form of heating places high demands on insulation and the tightness of gaps (draughts) in the building. A national model of 'standard and target values' has recently been developed for this. This model helps building owners to determine what level of insulation is most appropriate in the long term. The meaning and consequences of these 'standard and target values' will be incorporated in the periodic update of the WHAT map based on the latest insights.

Cooking gas

Besides heating, natural gas is also used for cooking or heating tap water. There are still many homeowners who use a clean heat alternative for heating, but still use gas for cooking and/or hot water. This also applies to many buildings that are already connected to a heat network. By better promotion of electric cooking, these can become completely natural gas-free. This has the financial advantage that when the gas connection is removed, the standing charge for natural gas is also eliminated. In Rotterdam some 17,500 households would qualify for this.

Transition Roadmap – "WHEN MAP"

In this section, we describe how buildings and areas can be connected to a natural gas alternative in time for Rotterdam to become natural gas-free by 2050. As discussed already, the construction of a collective, sustainable heat system is the best alternative for most of Rotterdam. Therefore, the municipality, together with building owners and suppliers of heat, must play an active role in the realisation of these collective systems. In this way, we can provide an affordable alternative to natural gas. This is already being done with the district-oriented approaches. The overall planning of promising district oriented-specific approaches is established in the WHEN map. Building owners are given plenty of time to make the switch, until it is no longer socially responsible to maintain the gas network for a select group. This is not yet the case.

The WHEN map shows a conditional planning of the promising districts. There are six preconditions that can influence this planning (Figure 41):

FIGURE 41: PRECONDITIONS FOR PLANNING

Based on the selection of promising districts, we will discuss with the central government what is needed to meet these preconditions so that we can actually start working in these districts. In doing so, we will work together with the other G4 cities and the Association of Dutch Municipalities (VNG). A final decision will only be taken if we can realise this ambition with the available powers and financial means. This may necessitate an adjustment of the ambition if they are insufficient. We will already start working in the meantime if there are opportunities to make use of no-regret developments and if we can make the switch feasible and affordable.

Promising areas for an integrated gas-free approach

In 2018, we started a district-oriented approach to natural gas-free heating in five districts. Based on our experiences in these, we drew up the first version of the WHEN map in early 2020. On this map, we have designated fourteen districts where we believe a subsequent district-oriented approach to natural gas-free energy is possible. We call these districts the exploration districts.

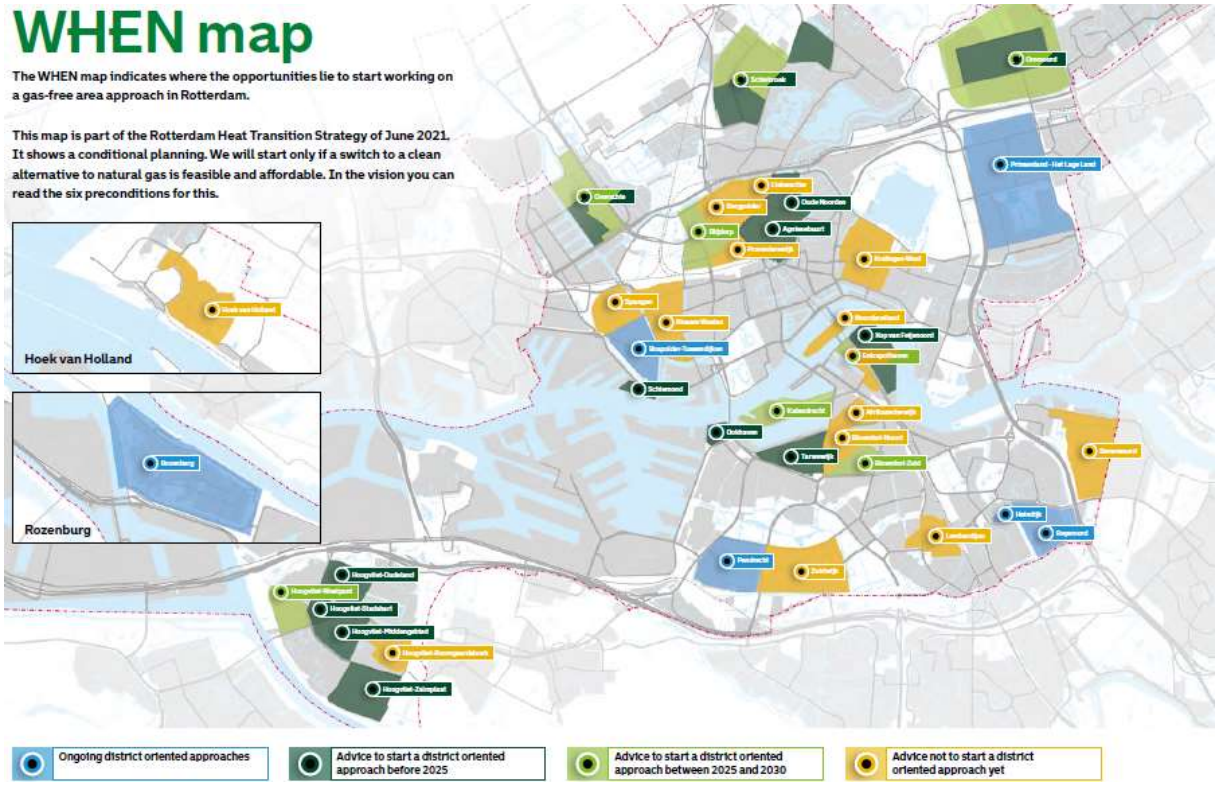


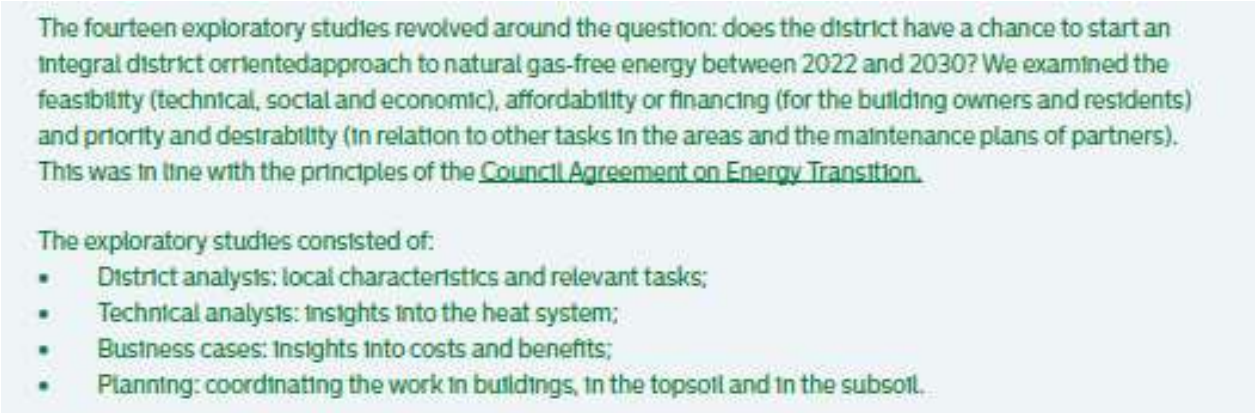
FIGURE 42: ROTTERDAM'S WHEN-MAP

In 2020, we further investigated these exploratory districts (see box). We collected information on various subjects, such as:

- **Linking opportunities:** Where can we join forces with partners? We looked at planned work on the sewer and gas pipelines. In this way, we can 'make work with work'. We also investigated whether the heat supply is spatially feasible. Finally, we discussed the maintenance plans of large property owners, such as housing corporations. This enabled us to discover where mutual gains could be achieved.
- **Feasibility and affordability:** In which districts is the transition to a gas-free model most feasible and affordable? We anticipate that the districts with many high-rise buildings will score well, due to their high densities of living units. The WHAT map

also indicates that a collective heat system is the most affordable solution in these districts.

- **Socio-economic benefits:** In which districts is there sufficient support and capacity to implement a gas-free system? Where can major steps be taken quickly or where can we link up with other social issues? Are there already residents or market initiatives in the district that can be linked to the heat transition?


The fourteen exploratory studies revolved around the question: does the district have a chance to start an integral district orrientedapproach to natural gas-free energy between 2022 and 2030? We examined the feasibility (technical, social and economic), affordability or financing (for the building owners and residents) and priority and desirability (in relation to other tasks in the areas and the maintenance plans of partners). This was in line with the principles of the Council Agreement on Energy Transition.

The exploratory studies consisted of:

- District analysis: local characteristics and relevant tasks;
- Technical analysis: insights into the heat system;
- Business cases: insights into costs and benefits;
- Planning: coordinating the work in buildings, in the topsoil and in the subsoil.

FIGURE 43: PROCESS OF CONDUCTING THE EXPLORATORY STUDIES FOR THE DISTRICT-ORIENTED APPROACH

Where do we start before 2030?

Based on the exploratory studies, we have proposed where and when we can best start with new district-oriented approaches. The results have been recorded on the WHEN map. In all these districts, the greatest opportunities lie in a collective alternative to natural gas (see What?). Appendix 1 explains why these districts were chosen. The proposal was made in consultation with parties both within and outside the municipality. It has also been reviewed by the district committees to which the exploratory districts are assigned.

The WHEN map

On the WHEN map we differentiate between:

- The current district-oriented approaches:
  Groot-IJsselmonde (Heindijk and Reyeroord), Pendrecht, Rozenburg, Bospolder-Tussendijken and Prinsenland-Het Lage Land;
- Promising districts to start a district-oriented approach before 2025: Agniesebuurt, Dokhaven, Hoogvliet (Middengebied, Oudeland, Stadshart & Zalmplaat), Kop van Feijenoord, Ommoord, Oude Noorden, Overschie, Schiebroek, Schiemond and Tarwewijk;
- Promising districts to start a district-oriented approach between 2025 and 2030: Blijdorp, Bloemhof-Zuid, Entrepothaven, Katendrecht and Hoogvliet (Westpunt);
- Districts where we will only start with a district-oriented approach after 2030: Afrikaanderwijk, Bergpolder, Beverwaard, Bloemhof-Noord, Boomgaardshoek, Hoek van Holland, Kralingen-West, Liskwartier, Lombardijen, Nieuwe-Westen, Noordereiland, Provenierswijk, Spangen and Zuidwijk.

With the selection of these districts (including the current district-oriented approaches and agreements in the Rotterdam Climate Agreement), we arrive at a total of 85,000 homes and buildings that are connected to the natural gas network and where we believe it is realistic to switch to a clean energy source before 2030. This puts us on track to meet the target for 2030 and 2050.

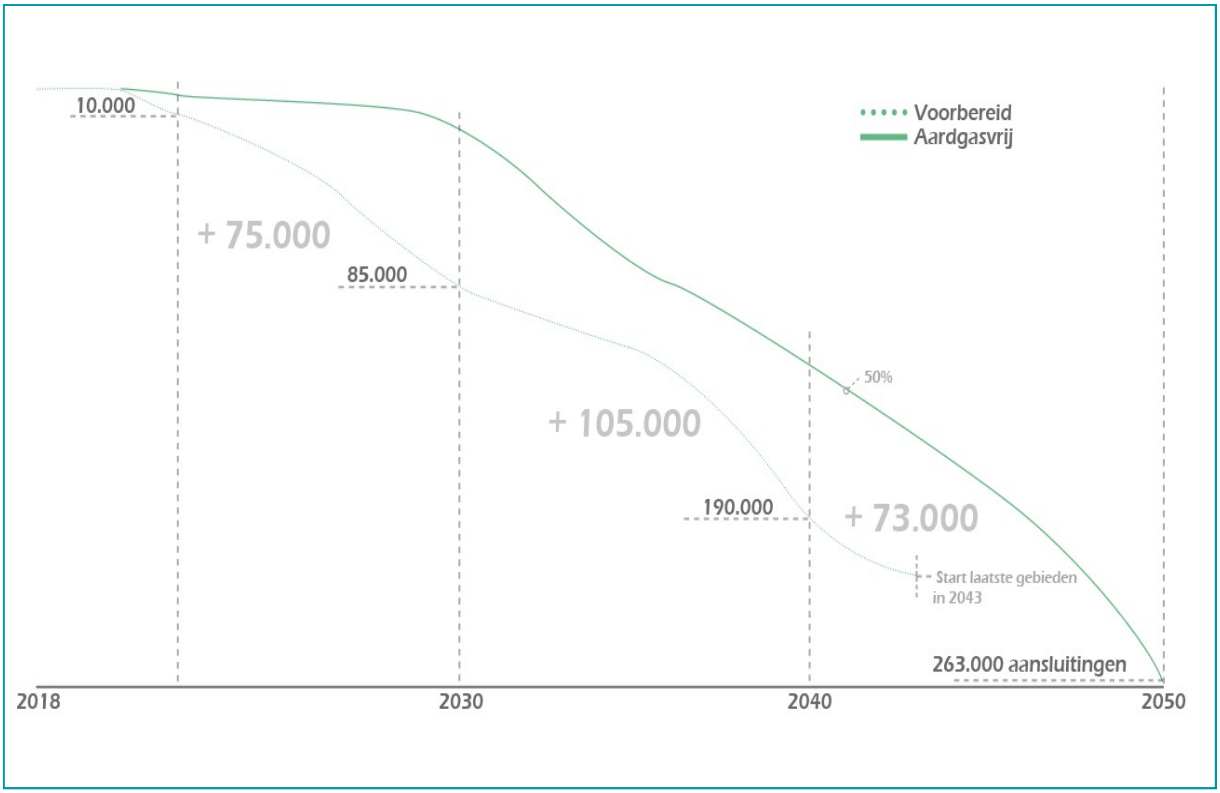


FIGURE 44: NUMBER OF BUILDINGS AND HOMES SWITCHED FROM THE NATURAL GAS GRID TO A CLEAN ENERGY SOURCE BY 2050

We have taken the following factors into account:

1. Distribution in space and time in the implementation with a view to liveability and accessibility;
2. Distribution in terms of investment costs and time for collective property owners;
3. The opportunities and consequences for the further development of the heat system;
4. The risk of delay.

In the districts that have not been designated as promising for a natural gas-free area approach before 2030 (yellow on the map), building owners can take steps in the right direction themselves. For example, by insulating their home or by individually switching to a natural gas-free alternative. An interactive version of the WHEN map will be made available on the Duurzaam010.nl website.

A provisional timetable

The planning indicated on the WHEN map is based on current knowledge. The decision regarding whether and when to start with new district-oriented approaches is up to the next Rotterdam council of mayor and alderman (2022-2026). This council will assess whether all preconditions are in place to make districts feasible and affordable free of natural gas. For

all Citizens of Rotterdam, it is now recommended to save on energy, to insulate their homes and to start cooking electrically, for example at obvious maintenance or replacement moments. The municipality will stimulate this with information and various forms of subsidies and loans.

Communication about the Heat Transition

As a municipality, we communicate actively about the Heat Transition. The focus is on the actions to be taken by residents. We make it clear that the plans are not yet fixed: before we can implement them, the necessary preconditions must be in place. Also, the new council has to first make a decision. Each time a new step in the decision-making process is taken, we will communicate about it. When the Heat Transition Strategy is adopted, we will communicate this through the usual channels.

Through online and offline channels (free local paper, district communication, social media, the duurzaam010 website), we will explain what it means to live in a promising district or not promising district where a natural gas-free approach can start before 2030. The online calculation tool will also soon be available on the website, which will give residents an indication of what a switch to a district heating network would mean for their energy bills. In addition, we are organising (online) question hours and workshops in cooperation with the home, environment and energy coaches from the Sustainability Shop(“Duurzaamheidswinkel”), the Houses of the neighborhood (“Huizen van de wijk”) and the Living Room Natural Gas Free in Pendrecht (“Huiskamer Aardgasvrij in Pendrecht”).

We will be posting general information about the heat transition on duurzaam010.nl. A more user-friendly version of the Transition Vision Heat and an interactive WHEN map will also be placed here. The map will show at street level whether or not you live in one of the districts that are likely to benefit from the start of a natural gas-free district-oriented approach before 2030. An extensive list of practical questions and answers can already be found on duurzaam010.nl. Such as: what do I do with my central heating boiler? This is in addition to the existing information, tips and financial opportunities that are available on duurzaam010.

Participation of stakeholders, residents and property owners

Many stakeholders were involved in the exploratory studies in the districts and in drawing up the WHEN map; parties from both inside and outside the municipality. This includes housing corporations, network operators, heat providers and district committees that have contributed to the process. Appendix 2 contains a complete list of the stakeholders involved. As soon as the next council takes a decision on the start of new district-oriented approaches, we will organise participation with residents and property owners in these areas. The best way to organise this will be determined together with the area committee, the district council or the district committee. Representatives of residents’ associations may also be involved here.

Appendix 1:

Ongoing district oriented approaches

Area	*District/neighbourhood*
Bospolder-Tussendijken	
Groot IJsselmonde	Heijndijk
	Reyeroord
Pendrecht	
Prinsenland-Het Lage Land	
Rozenburg	

Promising areas to start a natural gas-free district oriented approach before 2025

Area	*District/neighbourhood*	*Motivation*
Charlois	Oud-Charlois (Dokhaven)	Many opportunities for joint action with collective property owners and work in outdoor space and underground
	Tarwewijk	Many opportunities to work together with work in outdoor space and underground
Delfshaven	Schiemond	Opportunities for joint action with collective property owners
Hoogvliet	Hoogvliet-Noord (Oudeland)	Opportunities for joint action with collective property owners and work in outdoor space and underground
	Hoogvliet-Zuid (Middengebied, Stadshart & Zalmplaat)	Opportunities for joint action with collective property owners and work in outdoor space and underground
Feijenoord	Feijenoord	Many opportunities for joint action with collective property owners and work in outdoor space and underground
Noord	Agnesebuurt	Many opportunities for joint action with collective property owners and work in outdoor space and underground
	Oude Noorden	Many opportunities for joint action with collective property owners and work in outdoor space and underground
Prins Alexander	Ommoord	Opportunities for joint action with collective property owners and work in outdoor space and underground
Overschie	Kleinpolder	Opportunities for joint action with collective property owners and work in outdoor space and underground
	Overschie	
Hillegersberg-Schiebroek	Hillegersberg-Noord (110 Morgen)	Many opportunities for joint action with collective property owners and work in outdoor space and underground & market initiatives

Promising areas to start a natural gas-free district oriented approach before 2030

Area	*District/neighbourhood*	*Motivation*
Feijenoord	Bloemhof-Zuid	Many opportunities for joint action with work in outdoor space and underground
	Katendrecht	Opportunities for joint action with work in outdoor space and underground
	Kop van Zuid – Entrepot	Residents' initiative and opportunities for joint action with collective property owners and work in outdoor space and underground
Hoogvliet	Hoogvliet Noord (Westpunt)	Opportunities for joint action with collective property owners
Noord	Blijdorp	Residents' initiative and opportunities for joint action with work in underground

Areas that were investigated in the exploratory studies, but which do not yet have a chance of starting a natural gas-free district oriented approach before 2030

Area	*District/neighbourhood*	*Motivation*
Charlois	Zuidwijk	No opportunities for joint action with collective property owners and work in outdoor space and underground
Delfshaven	Nieuwe-Westen	Few opportunities for joint action with collective property owners and work in outdoor space and underground
	Spangen	No opportunities for joint action with collective property owners and work in outdoor space and underground
Feijenoord	Afrikaanderwijk	No opportunities for joint action with collective property owners and work in outdoor space and underground
	Bloemhof-Noord	No opportunities for joint action with collective property owners and work in outdoor space and underground
	Noordereiland	Few opportunities for joint action with collective property owners and work in outdoor space and underground
IJsselmonde	Beverwaard	Uncertainty about opportunities for joint ventures with collective property owners and work in outdoor space and underground & affordability
	Lombardijen	Few opportunities for joint action with collective property owners and work in outdoor space and underground
Hoogvliet	Hoogvliet Zuid (Boomgaardshoek)	Few opportunities for joint action with collective property owners and work in outdoor space and underground & social-economic factors
Hoek van Holland		Uncertainty about feasibility and affordability of alternatives to natural gas

Area	*District/neighbourhood*	*Motivation*
Kralingen-Crooswijk	Kralingen-West	Few opportunities for joint action with collective property owners and work in outdoor space and underground & social-economic factors
Noord	Bergpolder	Few opportunities for joint action with collective property owners and work in outdoor space and underground
	Liskwartier	Few opportunities for joint action with collective property owners and work in outdoor space and underground & social-economic factors
	Provenierswijk	Few opportunities for joint action with collective property owners and work in outdoor space and underground

Appendix 2:

Area	Type	Exploratory study/district oriented approach	Involvement
City Centre	Area committee	None	Informed in writing
Charlois	Area committee	Exploratory study	Presentation
Charlois Pendrecht	District committee	District oriented approach	Involved in ongoing district oriented approach
Charlois Tarwewijk	District committee	Exploratory study	Presentation
Delfshaven	Area committee	Area approach/exploratory study	Presentation on exploratory study and involvement in current district orientedapproach
Delfshaven Middelland	District committee	None	Informed in writing
Delfshaven Oud Mathenesse - Witte Dorp	District committee	None	Informed in writing
Feijenoord Afrikaanderwijk	District Council	Exploratory study	Informed in writing
Feijenoord Bloemhof	District Council	Exploratory study	Presentation
Feijenoord Hillesluis	District Council	None	Informed in writing
Feijenoord Katendrecht Wilhelminapier	District Council	Exploratory study	Presentation
Feijenoord Kop van Zuid-Entrepot	District Council	Exploratory study	Presentation
Feijenoord Noordereiland	District Council	Exploratory study	Presentation
Feijenoord Vreewijk	District Council	None	Informed in writing
Feijenoord wijk Feijenoord	District Council	Exploratory study	Presentation
Hillegersberg-Schiebroek	Area committee	Exploratory study	Presentation
Hoek van Holland	Area committee	Exploratory study	Presentation
Hoogvliet	Area committee	Exploratory study	Presentation
IJsselmonde	Area committee	Area approach/exploratory study	Presentation on exploratory study and involvement in ongoing district oriented approach
Kralingen-Crooswijk	Area committee	Exploratory study	Presentation
Noord Agnesebuurt	District Council	Exploratory study	Presentation
Noord Bergpolder	District Council	Exploratory study	Presentation
Noord Blijdorp	District Council	Exploratory study	Presentation
Noord Liskwartier	District Council	Exploratory study	Presentation
Noord Oude Noorden	District Council	Exploratory study	Presentation
Noord Provenierswijk	District Council	Exploratory study	Presentation
Overschie	Area committee	Exploratory study	Presentation
Pernis	Area committee	None	Informed in writing
Prins Alexander	Area committee	District oriented approach/ exploratory study	Presentation on exploratory study and involvement in ongoing district oriented approach
Prins Alexander Nesselande	District committee	None	Informed in writing
Prins Alexander Zevenkamp	District committee	None	Informed in writing
Rozenburg	Area committee	District oriented approach	Involved in ongoing area approach

Stakeholder	*Type of organisation*
Woonstad	Housing corporation
Woonbron	Housing corporation
Havensteder	Housing corporation
Vestia	Housing corporation
Habion	Housing corporation
Laurens Wonen	Housing corporation
MaasWonen	Housing corporation
SOR	Housing corporation
Woningbouwvereniging Hoek van Holland (WVH)	Housing corporation
Sportbedrijf Rotterdam	Operator of sports properties
Amvest	Real estate investor
Bouwinvest	Real estate investor
Heimstaden	Real estate investor
Manhave	Real estate investor
Vesteda	Real estate investor
Woonhave	Real estate investor
IVBN (club institutionele beleggers)	Real estate investor
Stedin	Grid operator
Vattenfall	Concession holder
Eneco	Concession holder/ geothermal permit holder/ party involved with aquathermia
Warmtebedrijf Rotterdam	Heating company
Energie van Rotterdam	Energy cooperatives umbrella organisation
Hydreco Geomec	Geothermal operator
Engie	Geothermal operator
Shell Geothermie	Geothermal operator
Enertrans/Schiebroek Warmte	Residual heat consortium
Waterschap Hollandse Delta	Water authority/ party involved with aquathermia
Hoogheemraadschap van Delfland	Water authority/ party involved with aquathermia
Buro Loo	Party involved with aquathermia
DWA	Party involved with aquathermia
TNO	Party involved with aquathermia
Jules Dock	Party involved with aquathermia
UHRIG Group	Party involved with aquathermia
VvE 010	HOAs collective
VvE Network Rotterdam	HOAs umbrella organisation
NetVerder	Network party
Burgerpanel Rotterdam	Citizen panel
The Municipality of Westland *In connection with exploratory study Hook of Holland*	Municipality
The Municipality of Ridderkerk *In connection with exploratory study Beverwaard*	Municipality

DECARB CITY PIPES 2050

Transition Roadmap City of Vienna

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 893509

Transition Roadmap of Vienna

Introduction

The City of Vienna is committed to achieving climate neutrality by 2040. The City can build on extensive groundwork as it has pursued a comprehensive strategic climate policy since the late 1990s when the City Council adopted the Climate Protection Programmes (KliP in 1999 and KliP II in 2009).

Vienna's climate goals were laid down in the government agreement of 2020 and adopted in the updated **Smart City Wien Strategy** (2022) by the City Council. They comprise objectives both for climate protection and climate adaptation. In combination, they are to safeguard the quality of life for all Viennese and are to accomplish climate neutrality and climate resilience.

The **Vienna Climate Guide** describes the path towards Vienna's climate goals until 2040 with a view to a climate-friendly city and outlines basic directions. It corresponds to a compact implementation strategy that identifies the common levers for climate protection (and climate adaptation). The measures to be given priority and the tools behind them are, however, not specified in detail nor are they finalised.

In concretization of the Climate Guide, the concept "**Raus aus Gas - Wiener Wärme und Kälte 2040**" ("Vienna Heating and Cooling 2040") takes on the building sector and outlines the path towards a climate-neutral city according to the motto "Raus aus Öl und Erdgas" ("Goodbye to Oil and Natural Gas") in the building sector.

Vienna's Transition Roadmap – the third central product / milestone in the context of the Decarb City Pipes 2050 project – comprises both, central parts of (verbatim where translation available) the **Vienna Climate Guide** (in German "Wiener Klimafahrplan", verbatim "Vienna Climate Roadmap") which deal with buildings and energy supply, and of the **Vienna's Heating and Cooling 2040 concept**.

The first chapter briefly elaborates the city of Vienna's climate strategy, while the second chapter gives a detailed outlook on Vienna's H/C sector in 2040. The third chapter outlines the main levers that are identified in the "buildings" and "energy" sectors to achieve this vision, and the fourth chapter details specific instruments to activate these levers.

The final chapter gives a brief outlook on the "Raus aus Gas" („Goodbye to Gas") programme, kicked off only in late 2022, which is the, cross-department process tasked with implementing the switch away from fossil heating systems from now until 2040

Status Quo & Goals for 2040

Figure 45 outlines the greenhouse gas balance for Vienna[23] and shows how overall greenhouse gas emissions have developed in Vienna since 2005 and which sectors have generated them. It presents all the emissions released to the atmosphere in Vienna, e.g. by heating systems, vehicles, power and heating plants, other combustion systems or diffuse sources. This "production-based" or "territorial" inventory is commonly used in international and national climate policy and follows standardised calculation methods.

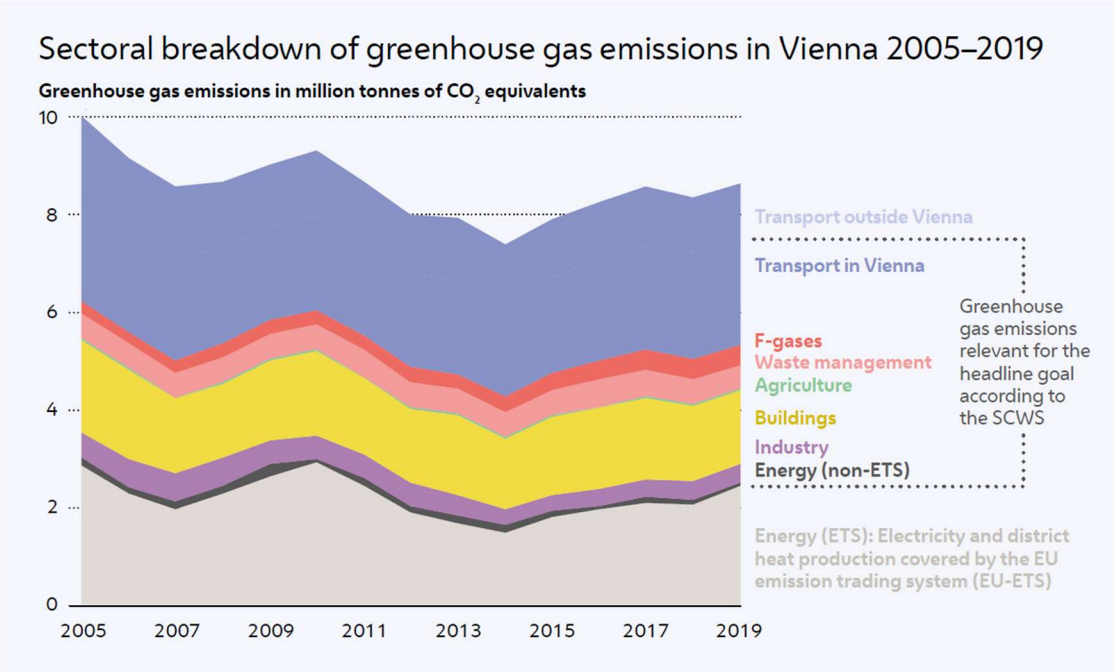


FIGURE 45: SECTORAL BREAKDOWN OF GREENHOUSE GAS EMISSIONS IN VIENNA 2005-2019 (SOURCE: VIENNA CLIMATE GUIDE)

Over the last 5 years, on average, almost 30 percent of the greenhouse gases relevant for Vienna's CO_2 headline goal were produced by **heating systems installed in buildings**.

In the "Energy" sector, more than 95 percent of emissions are produced by power plants with a capacity of more than 20 megawatts (e.g. power and district heating plants or co-generation plants) that fall under the scope of the European emission trading system (shown as "Energy (ETS)" in Figure X). Smaller plants with a capacity of less than 20 megawatts account for a minor share (shown as "Energy (non-ETS)" in Figure X). In accordance with the distinction between sectors covered by the ETS and sectors remaining a national responsibility, the emissions of plants subject to European emission trading are not included in Vienna's climate protection headline goals. In order to address, nevertheless, the major emitters subject to the ETS, the Smart City Wien Strategy and the Vienna Climate Guide still set ambitious objectives. However, they only indirectly relate to greenhouse gas (GHG)

[23] By the Environment Agency Austria

emissions by laying down pathways for the expansion of renewable energies in order to decarbonise the production of electricity and district heat.

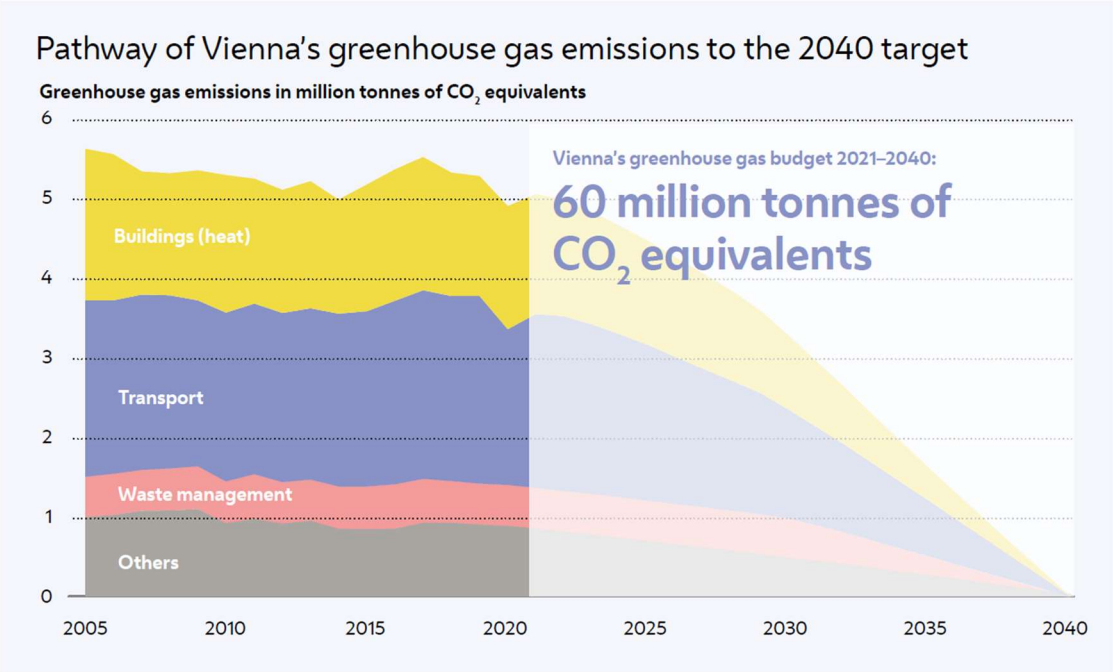


FIGURE 46: PATHWAY OF VIENNA'S GREENHOUSE GAS EMISSIONS TO THE 2040 TARGET (SOURCE: VIENNA CLIMATE GUIDE)

These greenhouse gas emissions relevant for the headline goal, as broken down by producers in Figure 46, are to be reduced to net zero by 2040 in line with the government programme of the Vienna City Government and the respective headline goal of the Smart City Wien Strategy.

Based thereon, the Smart City Wien Strategy defines targets for the development of greenhouse gas emissions in Vienna, energy consumption and Vienna's remaining "carbon budget" (see Figure 46):

Vienna's Climate Headline Targets

- Compared to the baseline year 2005, Vienna reduces local per-capita greenhouse gas emissions by 55 percent by 2030 and is climate-neutral from 2040 on.
- Vienna decreases its local per-capita final energy consumption by 30 percent by 2030 and by 45 percent by 2040 against the baseline year 2005.
- "Vienna's carbon budget": Vienna fixes its carbon budget remaining for the time from 2021 at 60 million tonnes of CO2 equivalents.

Core Priorities

In order to fulfil its emissions targets the following core priorities - relevant for heating and cooling - can be derived from these goals:

- **Goodbye to gas in heat generation** by reducing the heat consumption of buildings and by switching to district heating and the use of ambient heat by

means of electricity-powered heat pumps. As a large share of these emissions stems from gas heating systems, Vienna's climate policy has to address them as a priority.

- The **decarbonisation of electricity and district heat production** is to be made possible by the expansion of renewable energies in Vienna and Austria.
  Green gas is to be available for co-generation plants and other energy-efficient applications but not for heating buildings or supplying hot water in Vienna. Nuclear energy remains excluded as part of the solution.

Buildings

From 2014 to 2018, Vienna's building sector, specifically heating, cooling and hot water supply, accounted on average for almost 30 percent of the greenhouse gas emissions of relevance for the headline goal. Oil- and coal-fired heating systems hardly play a role here. **Almost 90 percent of CO_2 emissions recorded in the building sector are generated by gas heating systems** — mostly by around half a million gas boilers in homes or workplaces and, to a minor extent, by gas-fired central heating systems serving one or more buildings.

Apart from waste management, **the decarbonisation of the building sector may be the biggest challenge on the way towards climate neutrality in Vienna**. This is due to the following reasons:

- The **legal framework for ensuring security of planning and investments**, both for building and home owners and energy suppliers and system operators, is still lacking. Especially the provisions of housing law and the Natural Gas Sector Act applying to multi-family and multi-storey residential buildings as well as mixed use buildings prevailing in Vienna constitute major obstacles to decarbonisation. The basic conditions required for the transition in heating are just being prepared or under political discussion at both the federal and Viennese levels.
- **There is not much time left until 2040**: The refurbishment or replacement cycles of relevant building parts and heating systems are measured in decades. In the building and heating sector, in particular, changes are therefore much lengthier than in other sectors. If the phase-out is to be completed for oil by 2035 and for gas by 2040, numerous heating systems will have to be replaced before the end of their technical service life.
- **Hundreds of thousands are affected**: The necessary conversion measures require interventions in hundreds of thousands of apartments and tens of thousands of buildings that will be felt by many people and, for some of them, will result in changes to their habits. The expansion of the district heating system will temporarily be visible and audible in many streets.
- **More well-qualified key workers are needed**: Key sectors are partly affected by a lack of appropriately qualified workers. Both the massive increase in the thermal rehabilitation of buildings and the installation of many more climate-friendly heating systems require more specialised workers and, therefore, timely qualification programmes and re-trainings but, at the same

time, give an enormous boost to employment and value creation in the labour market and for the economy of Vienna.

- **Costs are incurred**: It will not be possible in each case to finance the conversion measures from the reserves established for buildings. And it will not be possible in each case to compensate these one-off costs by lower expenditure on energy within a reasonable period of time. Thus, tailored solutions have to be found for this problem, too, in order to protect Vienna's residents against excessive financial burdens.

Climate protection goals for the building sector:

- We completely phase out fossil heat supply by 2040.
- The final energy consumed per capita by heating, cooling and hot water systems in buildings decreases by 20 percent by 2030 and by 30 percent by 2040
- Related per-capita CO2 emissions fall by 55 percent by 2030 and to zero by 2040
- Developers' competitions in subsidised housing accelerate social innovations and new solutions for climate protection and climate adaptation.

In the government agreement, the City Government also laid down that:

- *"Fossil fuels are phased out for heating, cooling and hot water supply by 2040."*
- *"…green gas, including hydrogen from renewable energy sources ... is to be used for co-generation plants or other high-grade energy purposes rather than for heating and hot water supply in Vienna."*
- *"Within the next two years, a concept will be developed for the gradual switch from fossil-fired heating systems to district heating and renewable heating systems in existing buildings by 2040…"*

Energy Supply and Infrastructure

Decarbonisation and the massive expansion of electricity and district heating systems entail challenges, as renewable energy sources must be integrated to an unprecedented degree within a relatively short timeframe. In its turn, this calls for the expansion and restructuring of the respective grid and storage infrastructures. Achieving this ambitious goal while preserving the reliability and affordability of energy supply will make high demands on all parties involved. At the same time, it is clear that the renewable energy sources to be tapped in order to reach this goal must be CO_2-free and should originate largely in Vienna and the surrounding region. This makes us less dependent on geopolitical imponderables in the countries of origin of petroleum and gas or along transport routes. The regionalisation of energy supply will also enable us to face occasionally skyrocketing energy prices on the world markets with some serenity and allow us to expect more stable energy costs with long-term affordability.

As indicated above, emissions from plants with an installed capacity of less than 20 megawatt fall under the national scope of responsibility and those from larger plants with an

installed capacity in excess of 20 megawatt are covered by EU emission trading and therefore excluded from the headline goal. Thus, the Smart City Wien Strategy does not set any fixed targets for 2030 or 2040 to be complied with by Vienna's energy sector. However, targets for the expansion of the renewable energy generation sector within Vienna's municipal territory as well as for the share of renewables in the final energy consumption of the city were laid down and must be implemented essentially – but not exclusively – by the energy industry:

Goals for energy supply and infrastructure

- By 2030, renewable and decarbonised energy generation in Vienna equals three times and, by 2040, six times the volume of 2005.
- Vienna's final energy consumption will be covered by renewable and decarbonised sources at a rate of 50 percent in 2030 and entirely by 2040.

In addition, Vienna's government agreement of 2020 defines **short-term targets for expanding the photovoltaics sector** within the municipal territory:

- Vienna increases its electricity generation within the municipal territory by means of photovoltaics (PV) at least to 250 MW_{peak} by 2025 and to 800 MW_{peak} by 2030. These targets will be reviewed in 2023 regarding their technical and economic viability and stepped up, if possible.

Vienna's H&C Outlook 2040

Vienna's Heating and Cooling vision for 2040 at a glance

100 % renewable energy for heating and cooling. The city's vision is to heat and, where necessary, cool all buildings in Vienna in a climate-neutral, emission-free and renewable way in 2040. Fossil fuels will no longer be needed for heating and cooling.

The central district heating network mainly supplies the densely built-up areas and will be re-densified especially where district heating is already available. District heating will thus supply a high proportion of existing buildings in areas of the city with a high heat demand density. In addition to the expansion, district heating will also be decarbonised, so that by 2040 fossil energy will no longer be needed to generate district heating. Local heating networks will be built for area and neighbourhood solutions in those areas of the city that are not suitable for the central district heating network despite high heat density. Renewable building heating systems are used in new buildings and also for existing buildings in areas with a rather low heat demand density. The renewable on-site potentials will be used in the best possible way and integrated into the respective energy system. There are isolated gas

supply areas for industry and power plants that produce electricity and heat and are fed with green gas.

This vision is based on the current heat demand density in the individual areas and the existing district heating routes. The district heating network has been developed in the past in such a way that areas with a high heat demand have been developed.

In addition to the heat demand density, other technical, economic and legal restrictions must also be taken into account in the future when expanding the grid.

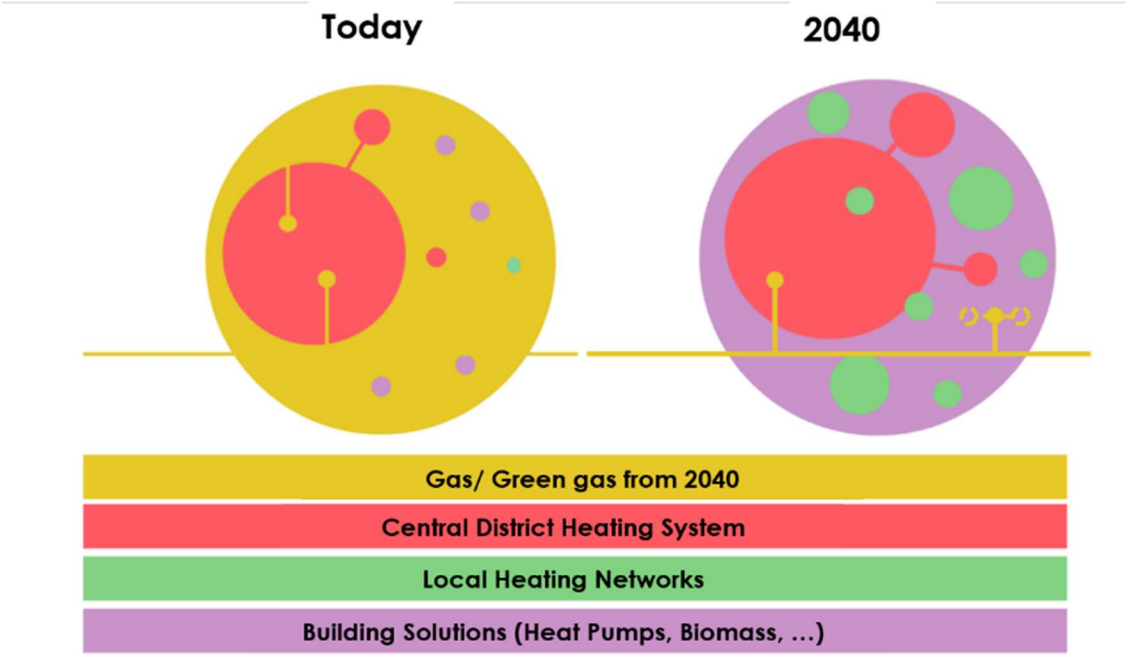


FIGURE 47: HEATING AND COOLING – TODAY AND TOMORROW (SOURCE: CITY OF VIENNA, ENERGY PLANNING)

Based on different previous projects mapping spatial heat demand and through information exchange with the DSO in Vienna, the draft H/C Plan for 2040 was established (and previously submitted for Deliverable D3.3). It highlights the spatial distribution of energy solutions with the dense inner city dominated by district heating (existing respectively with planned extension) and outer districts and less densely populated areas more suitable for single solutions.

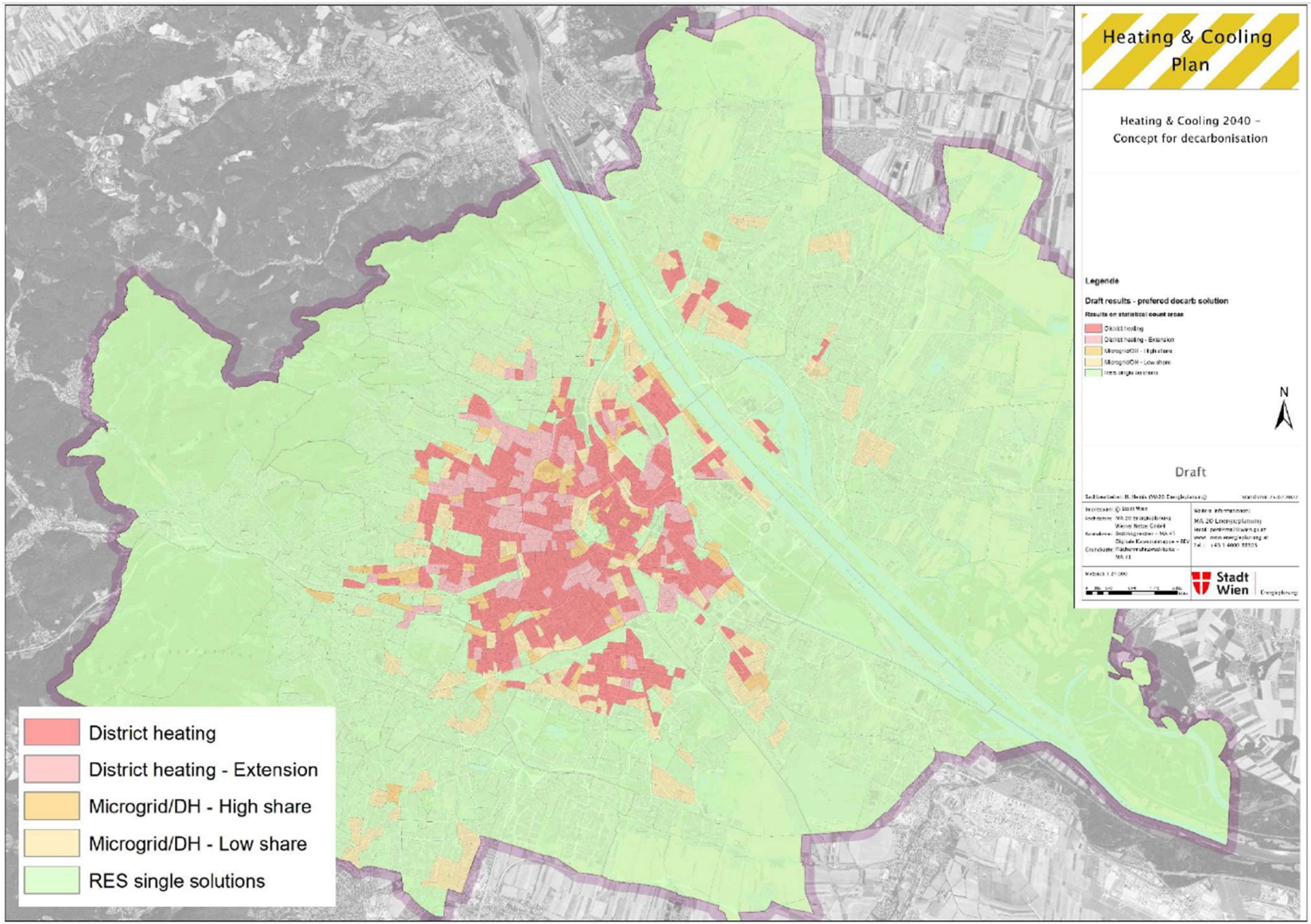


FIGURE 48: VIENNA'S HEATING AND COOLING PLAN (SOURCE: VIENNA HEATING AND COOLING PLAN)

Pathways and Levers

Buildings

The reduction of per-capita CO2 emissions by 55 percent by 2030 and to zero by 2040 requires that final energy consumption and the energy mix develop as shown in Figure 49. Due to the increasing number of refurbished buildings, final energy consumption falls in the building sector in absolute terms, in spite of expected further population growth that results in a rise of the heated area by more than 50 m² per additional resident (in housing plus non-residential buildings). The share of gas in final energy consumption declines from more than 40 percent today to less than 30 percent by 2030 and to zero by 2040. The remaining use of fuel oil is to be finally consigned to the files of history by 2035. Gas heating systems are primarily replaced by district heating, which will be substantially expanded, or heat pumps.

The pathways shown below do not envisage a linear development from now to 2040 but rather a “ramp-up” of heat/energy measures from approximately the mid-2020s on.

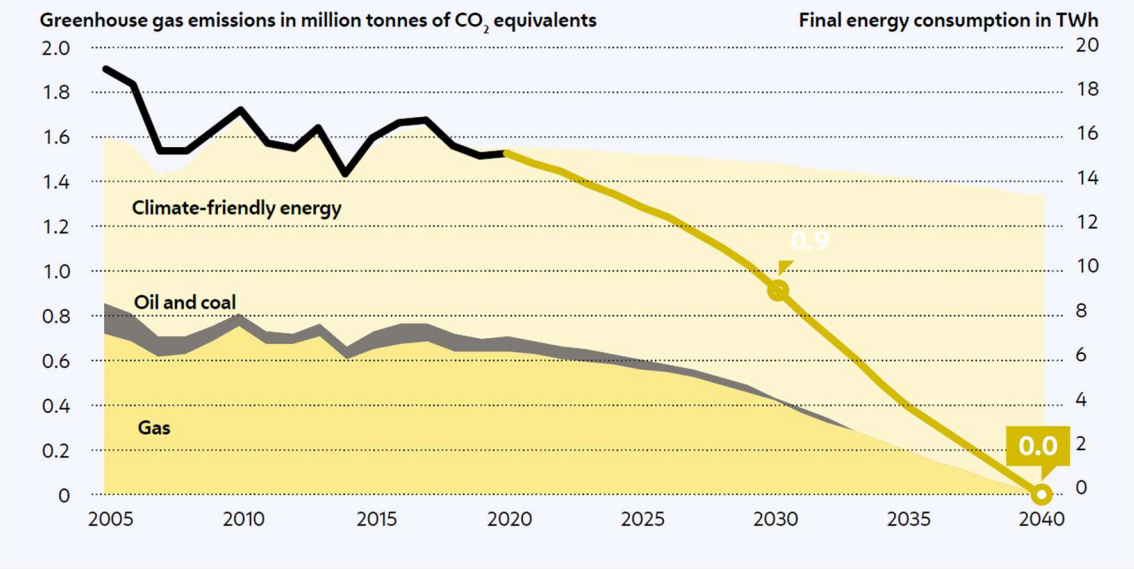


FIGURE 49: PATHWAY OF GREENHOUSE GAS EMISSIONS IN THE BUILDING SECTOR BY 2040 (SOURCE: VIENNA CLIMATE GUIDE)

The initially low replacement rate — see Figure 50 — is based on the assumption that a substantial upward trend and the required multiplication of both annual new connections to the district heating network and annual installations of new heat pumps can only be expected after the framework conditions relevant for Vienna will have been adapted at the federal and Viennese levels.

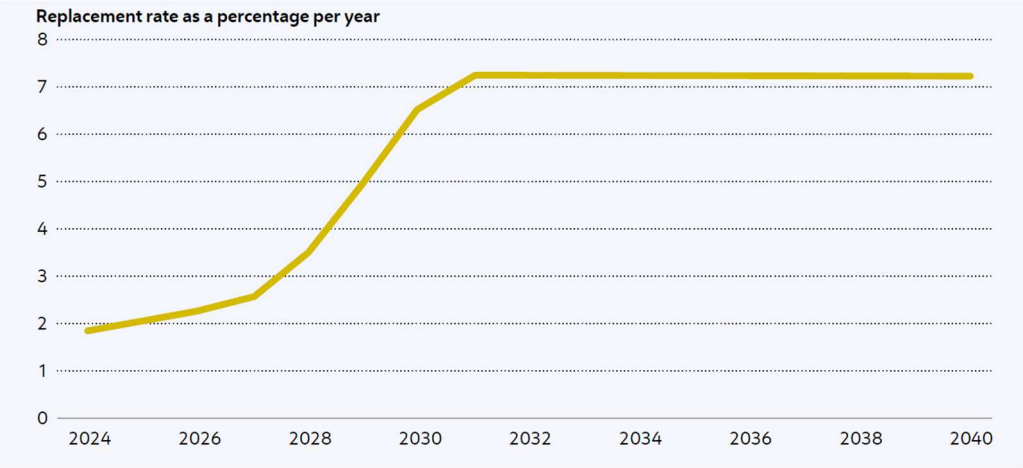


FIGURE 50: PATHWAY FOR ANNUAL SWITCHES FROM RESIDENTIAL GAS HEATING SYSTEMS TO CLIMATE-FRIENDLY SYSTEMS (SOURCE: VIENNA CLIMATE GUIDE)

It is all the more important to put in place and communicate swiftly the changes outlined below in order to ensure a high level of security of planning and investments for all. This is what building owners need for the replacement of their heating systems on the one hand and what system operators and energy suppliers require for the timely provision of network infrastructures and production capacities for additional district heating connections and heat pumps on the other hand. And, finally, clarification is needed on how all this can be accomplished while ensuring social sustainability.

Lever 1: Creating the framework for phasing out fossil heating systems

The key to decarbonising heating supply in Vienna is the phase-out of fossil heating systems. To this effect, several fundamental measures have to be implemented so that clarity prevails among citizens and businesses on the one hand and a strategic framework providing orientation is defined on the other hand.

- **Creating a clear legal framework:** Specific rules are needed for phasing out oil and gas heating systems on a legislative basis. Vienna's endeavours are currently supported by the negotiations on the Renewable Heat Act at the federal level. It is planned to regulate the phase-out of fossil heating systems at the federal level while also laying down reliable and adequate provisions cushioning the social impacts. On this basis, Vienna will adopt legislation adding important details and rules specifically necessary for densely built-up urban space.
- **Creating data bases:** The collection and compilation of a robust basis of data at the building and apartment level is essential for the gradual and spatially co-ordinated replacement of fossil heating systems as well as other fossil-fired system, for example in craft businesses. The legal basis for these efforts will be created at the provincial level.
- **Supporting tools of integrated spatial and energy planning:** Among others, one essential regulation that still needs to be introduced in the Building Code for Vienna is the extension of integrated spatial and energy planning from new buildings to existing buildings and heating systems. At the transition to the citywide phase-out of fossil heating systems, integrated

spatial and energy planning is an opportunity for advancing the switch – differentiated in space and time – to district heating or renewable energy systems and supporting a co-ordinated modification of energy infrastructures that satisfies spatial demands and comes at the best cost possible. What is envisaged at present is a zone model that prioritises different heat supply options depending on infrastructure availability and shows the time of availability in a phased approach within the framework of the integrated spatial and energy plans for existing buildings. The related ideas are specified in concrete and partly also in spatial terms in the “Heating and Cooling Vienna 2040” strategy (see below).

- **Decarbonising district heating:** In a large part of the densely built-up urban area, a switch from gas heating systems to district heating is the most important measure for decarbonising the building sector. From an overall perspective (also taking account of the emissions of the energy and ETS sectors), however, this strategy only makes sense if district heat is produced without fossil fuels. The way in which this can be accomplished and which measures will be taken by Vienna (also including the additional framework conditions required) is explained in Chapter 4.6 “Electricity and district heat generation”.

Lever 2: Reducing energy consumption and using renewable heating systems

In order to accomplish the desired reduction of final energy consumption, the number of flats that are thermally rehabilitated per year has to be increased to 25,000 in the next few years and then kept at this level until 2040. A similar development is needed for non-residential buildings. On average, each rehabilitation project should, if possible, halve the energy used for heating and optimise the energy used for hot water supply, as the latter will increase on average as a result of the frequent centralisation of hot water systems. In addition to thermal rehabilitation measures, heating systems, too, are to switch to district heating or renewable energies in the course of energy-related refurbishment, which frequently requires the centralisation of hot water supply.

Tailored programmes are needed that offer and support appropriate solutions for buildings. Both the type of climate-neutral energy supply and meaningful thermal rehabilitation measures depend, first, on the location of a building in one of the zones identified in the integrated spatial and energy plans and, second, on the type of building (e.g. historical office building or residential building from the 1960s).

Therefore, we are working on the following measures and programmes:

- **Programmes promoting thermal rehabilitation and boiler exchange:** Building on decades of experience and on the reflections on the integrated spatial and energy plans for existing buildings, appropriate, targeted promotion programmes are to be developed and framework conditions are to be adapted. The aim of promotion always has to be both the provision of incentives and the equally vital cushioning of social effects of a switch to renewables or district heating — as far as possible in combination with meaningful thermal rehabilitation measures. Within the framework of the

heating strategy, the Federal Government signals additional funding lines that also are to address multi-storey buildings and will provide financial support to people obligated by regulatory requirements to make investments. Here, it is important to ensure that promotion programmes are co-ordinated between the Federal Government and the federal provinces and that adequate funding is provided for Vienna's plans (e.g. centralisation of heating systems and replacement of gas boilers). The budget volumes have to be sufficiently high for achieving the objectives and secured in the long-term and should be co-financed by the federal level. In particular, the financial support provided has to ensure the very generous cushioning of social effects for people who cannot afford the conversion of their heating system.

- **Training programmes and labour market initiatives:** The investment volume unleashed by the planned thermal rehabilitation and energy-related refurbishment drive amounts to significantly more than one billion euro per year. At the same time, such a programme strengthens numerous economic sectors and creates or secures in excess of 15,000 jobs. These effects stimulating the labour market are to be supported by appropriate training programmes and labour market initiatives.
- **Pilot programmes, such as "100 buildings: Bye, bye gas boiler, hello renewables":** Work is to be performed on various programmes and demonstration projects. In this context, however, numerous technical, organisational, legal and financial aspects of the business models still have to be clarified. The pilot and demonstration programme "100 buildings: Bye, bye gas boiler, hello renewables" is to develop solutions for the particular challenge of switching from gas boilers to renewable energies. In addition, we need a promotion and networking programme that supports pilot projects implemented at the interface between research, demonstration and dissemination and is backed and funded by the City of Vienna (ideally with co-funding from the Federal Government and/or the EU). This programme is to be set up soon. What is especially important here is the full transparency of planning, the evidence obtained and the implementation of such pilot projects, as this is a requirement for a broad rollout, including the provision of training to energy consultants and authorities.
- **Accompanying programmes, such as consulting, dissemination of information, awareness raising:** In Vienna, for example, the "Hauskunft" counselling service is to be upgraded into a one-stop shop for all issues related to the refurbishment of buildings and the switch to new heating systems. Vienna will also prepare a timely, comprehensive information campaign with a broad impact in order to make the building owners concerned as well as citizens and the enterprises needed for implementation aware of the new legal requirements and the related financial or other support offered by the City of Vienna.
- **Voluntary agreements** – so-called "**climate alliances"** – between the City of Vienna and large building owners and managers or enterprises are to

create a platform for mutual assistance on the way to an oil-and gas-free building stock.

- **The City of Vienna and its undertakings as a role model:** The aim is to heat buildings occupied by municipal authorities exclusively by means of climate-friendly energies by 2035 and to equip them with photovoltaic systems wherever technically feasible in the next few years. By 2025, municipal undertakings are to draw up a plan on how their building stock can be decarbonised by 2040 and which buildings are to switch from fossil fuels to district or renewable heating by 2030.

Energy Supply and Infrastructure

It depends on many factors which solution can be sensibly implemented and where. In the future, renewable energy solutions will be combined in the best possible way so that appropriate solutions are available for all framework conditions. To avoid being limited to lighthouse projects, easily replicable solutions must be implemented and the heating system switch rate successively increased. A variety of renewable sources and waste heat are available for this purpose.

Renewable electricity in the heat transition

In the future, Vienna will be supplied with heating and cooling mainly by decarbonised district heating and heat pumps. Both technologies require electrical power for their operation. Due to the large number of buildings that will be converted from gas supply to a heat pump solution, it is currently expected that the annual electricity consumption for space heating and hot water will increase from currently 1.8 TWh to 2.7 TWh, which corresponds to an increase of 50%. Decarbonised district heating will also have an increased electricity demand, as heat pumps, large-scale heat pumps and deep geothermal energy will account for a large share of district heating in the future. Here, an increase from 0.50 TWh to up to 0.85 TWh is expected. This corresponds to approx. 10% of Vienna's total electricity demand.

For a climate-neutral Vienna, this electricity must of course come from renewable sources. Due to the urban structure, which only allows wind energy use to a very limited extent, and the planned phase-out of fossil energy in electricity production, Vienna's electricity production will decrease by 2040 despite the existing solar power offensive. Photovoltaics will play an essential role for Vienna, as this technology can be well integrated especially in buildings. With the Vienna Solar Power Offensive, which was launched in 2021, work is already underway to increase the installed PV capacity from currently around 100 MWp to 800 MWp by 2030. The focus is on the use of areas that are already sealed.

Wind energy will play an important role in Austria's electricity production, but only a limited one in Vienna. Due to the dense development, Vienna offers hardly any suitable locations for wind power plants. The expansion of hydropower is also only possible to a very limited extent within Vienna.

Accordingly, Vienna will cooperate with the surrounding area. As a large city with high energy consumption, Vienna is required to use the renewable electricity surpluses from the surrounding area and act as an energy storage facility. In order to be able to safely distribute

the increasing amounts of electricity in Vienna's power grid in the future, continuous grid expansion is necessary.

Renewable ambient heat

Locally available heat is an essential component for future energy supply. In urban areas, geothermal heat, heat from groundwater and heat from the air can be extracted by means of heat pumps and used for individual or several buildings. In addition, solar thermal energy offers a valuable supplement. Heat that is available at great depths can be fed directly into the central district heating system by using deep geothermal energy. In this way, renewable sources on the outskirts of the city can be used to supply dense urban districts.

Waste heat as a renewable energy source

In order to replace fossil fuels and switch to district heating on a large scale, the direct use of waste heat is an important component. Waste heat from high-temperature applications, e.g. from waste incineration plants or combined heat and power (CHP) plants, can be fed directly into the district heating network due to the high temperature level. Low-temperature waste heat sources, such as waste heat from sewers or waste water heat, can still be used for space heating and hot water preparation by means of heat pumps. Other sources of waste heat are office buildings, supermarkets, commercial enterprises and data centres or server rooms. Waste heat sources must be used locally in the best possible way by coordinating energy requirements with locally available sources as early as possible and taking them into account in planning processes at an early stage (for example in district solutions for heat production for flats). Seasonal storage of waste heat, e.g. in geothermal probe fields, can make surplus heat in summer usable as a heat source in winter.

In the future, the electricity demand for cooling in Vienna will also increase significantly (according to the Compass Lexecon study by 240 % from approx. 300 GWh in 2019 to more than 1 TWh in 2040). An increased use of individual cooling and air-conditioning devices in this context would also mean an increased release of waste heat into the urban space, which would further heat up the city in the summer months. This development must be countered with alternative solutions such as district cooling networks (especially for service buildings) or seasonal building cooling using geothermal probes. Currently, many waste heat flows are still discharged unused into the environment. Appropriate regulations will be needed to ensure that waste heat is used in the best possible way.

Biomass - limited use in the city

In Vienna, the use of biomass (e.g. wood pellets, wood chips or logs) in heating systems of single and multi-family houses as well as in multi-storey residential buildings is currently at a very low level. In addition, biomass contributes a small part to district heating production. An increased use of biomass for heat supply in the Viennese building sector is also not planned for the future. Biomass only grows to a limited extent each year and is therefore not sustainably available in unlimited quantities. In addition, climate change has a negative impact on domestic wood species in some cases. Not least for logistical reasons, bioenergy should rather be used close to its origin, i.e. in rural areas. Moreover, biomass is a high-quality energy source with a high energy content, which should therefore not be used primarily in the low-temperature range, but for higher-value uses.

If there are reasons for excluding the use of heat pumps or connection to district heating, the use of biomass in individual heating is in any case a suitable alternative. Biomass is especially suitable where a lot of energy is needed in a small area, as it is a relatively dense energy store and can also generate high-temperature heat. In multi-storey residential buildings outside the district heating area, the energetic use of biomass could be used in isolated cases as a central heat supply. One advantage here would be the efficient central flue gas cleaning compared to many individual heating systems.

Green gas for industry and power plants

It can currently be assumed that even in 2040 and beyond, the availability of green gas in Europe will be quantitatively limited and correspondingly expensive. The reasons for this are the high demand for different areas of application (e.g. chemicals, steel, aviation and shipping) and the production and supply structures that are still being developed. Against this background, the already scarce quantities of green gas in Vienna will not be used in the low or medium temperature range and thus not in individual buildings to supply them with heating and hot water. Vienna will continue to rely on gas-fired plants to maintain and cover peak loads in the electricity and district heating supply. The use of green gas is advantageous here due to its high energy density and seasonal storage capability. The use of green gas is therefore only envisaged for Vienna where there are no other alternatives, such as in CHP plants, in high-temperature applications in production and temporarily in parts of public transport.

It is of great importance for Vienna that green gas is available in sufficient quantities and at acceptable prices for the above-mentioned areas of application. Incentives must be created to make the best possible use of the potentials in Vienna and to enable the development of green gas production and use.

Joint implementations

In the coming years, measures for the decarbonisation of the building stock, measures for climate change adaptation and measures in the field of mobility will require space in the public space. In order to be able to take as many aspects as possible into account in individual projects and to proceed in a coordinated and holistic manner, a suitable coordination office must be established. This ensures that all of the aforementioned topics are considered in the course of a project. This can reduce investment costs, construction site times and the impact of construction noise.

Switching from fossil fuels to renewables for energy supply on the one hand entails the reduction of fossil, emission-intensive energy sources and greater energy efficiency. On the other hand, it increases the demand for environmentally friendly forms of energy. The chart below gives an overview of how electricity and district heat generation, which currently is still largely based on fossil fuels, is to be transformed into a climate-neutral system by 2040.

Lever 1: Tapping renewable electricity potentials on site

In the field of renewable electricity generation in urban areas, special importance must be assigned to photovoltaics (PV). Vienna plans to step up electricity production by means of PV within the city from currently 50 MWpeak (2020) to 250 MWpeak by 2025 and to 800 MWpeak by 2030. In this, Vienna will apply the following levers:

- **Mobilisation of surfaces on built structures and plots owned by the City of Vienna or associated facilities:** Evaluation of suitability by 2022, implementation of PV plants on buildings and land owned by the City of Vienna by 2025; target: 50 MWpeak on buildings owned by the Vienna City Administration.
- **Utilisation of all technical space potentials and fostering of the installation of innovative PV solutions well adapted to urban conditions:** In addition to roof and façade surfaces, this concerns above all plants in public and semi-public space, such as parking lots, noise barriers, motorways, underground and aboveground rail lines, shading installations for halls and outdoor areas.
- **Simplification of approval procedures** and adaptation of legal framework conditions in the Vienna Electricity Management Act and in provisions under construction law.
- **Special subsidy programme for community PV plants:** In highly condensed urban agglomerations such as Vienna, the roofs of apartment buildings are of enormous importance for increasing the PV volume. The installation and maintenance of such plants is substantially more costly than that of PV plants mounted on other surfaces. Therefore, a subsidy bonus could prove a key investment incentive to step up such installations.
- **Increase of subsidies and creation of new subsidy programmes,** e.g. innovation funding for multi-purpose plants including PV plants on parking lot roofings or carports, building-integrated or floating PV plants; subsidies for lightweight and foil modules to tap large-surface potentials on halls; combined subsidies for PV-cum-storage devices.
- **Mobilisation of owners of large-scale roof surfaces suited for PV installation (housing developers, industry and trade):** Assistance provided through customised information and support packages; Solar Prize of the City of Vienna.
- **Wider obligation to install PV** plants on all newly built structures as well as for all larger structural modifications of roofs.
- Support of further network expansion in integrating additionally created PV capacities.
- **Broad awareness raising and solar energy campaigns:** “My City, My Power Plant”; Vienna invites all citizens to become part of the Vienna PV offensive; counselling for renewable energy communities; development of a centre for renewable energy resources to provide advice and information about subsidies and necessary approvals related to renewable energy resources.

Lever 2: Ensuring renewable district heating

As owners and operators of central infrastructure facilities, the City of Vienna and the Vienna public utilities (municipal enterprises) find themselves in the favourable position of being able to shape the transformation of energy generation to a significant extent. At the same time, it is evident that entrepreneurial decisions need conducive framework conditions in this area as well – especially since this will involve investments totalling several billions of euro

until 2040. And these framework conditions must be delivered by both the City of Vienna and the Republic of Austria!

The possibilities open to Vienna include the following:

- **Unlimited support by the City of Vienna**, also in its capacity of owner, **for decisions to be taken by the managements of the Vienna Public Utilities** (Wien Energie, Wiener Netze) regarding
  - Tapping and integration of large-scale deep geothermal energy potentials,
  - Integration of ambient and waste heat potentials by means of large-scale heat pumps,
  - Expansion of the district heating network, specifically in inner-city areas, but also in zones with high thermal density independent of the centralised integrated grid (local neighbourhood heat networks, anergy networks),
  - Implementation of heat storage units.
- **Quick and optimised support of projects** designed to enhance the share of renewables, to be extended by the City of Vienna in the course of administrative procedures (under water law, construction law, law on industrial and commercial plant operation, land use law).
- **Incentives and/or regulatory frameworks for the rapid connection of existing buildings** and all dwellings inside them to district heating as soon as the district heating grid is available in the area in order to safeguard that investments in the district heating grid can be quickly refinanced.
- **Integrated Spatial and Energy Planning 2.0:** Extension of this approach combining climate protection and spatial planning (see Article 2b of the Building Code for Vienna) to the existing building stock; development of planning materials for optimising the selection of suitable energy sources and technologies for fossil-free heating by 2040 in co-ordination with existing settlement structures and infrastructures as well as heating providers.

Lever 3: Using green gas to cover peak loads

- **Conscious utilisation of green gas:**
- In the future, green gas is to be used in Vienna for co-generation plants or other applications of high energetic benefit, but not for space and water heating.
- **Continued operation of power plants and co-generation plants fuelled by green gas** to cover peak loads and for stabilising the power grid in and around Vienna.

Instruments to be used

"How do we go about it?" is probably the most essential question before major transformations. The complexity of decarbonising the city of Vienna, with its countless buildings and diverse framework conditions, requires thoughtful planning. This way, the right

measures can be taken at the right time. To this end, this chapter provides tools to achieve and influence the 2040 target. These instruments are constantly being further developed so that they support the implementation of the building blocks in the best possible way.

Instrument 1: Spatial energy planning

With the ordinance of spatial energy plans according to § 2b of the Building Code for Vienna, a basis for spatial energy planning has already been created, which supports the expansion of district heating and the use of renewable energies in new buildings.

The next step will be to extend spatial energy planning to existing buildings and heating systems. In doing so, it will be increasingly important to address the starting situation of the existing building stock and, against this background, to shed light on the different possibilities for switching energy sources. Depending on locally available energy sources (district heating available yes/no, renewable potentials), structural building parameters (partial thermal renovation/refurbishment required or already carried out, furnishings of the dwelling, possibly listed buildings/protection zones) and other relevant aspects, appropriate framework conditions must be developed, e.g. on the planning, legal and subsidy policy side.

The parameters mentioned above result in different solution options within the urban area, the development of which can be supported and driven forward in a coordinated manner by energy space planning. Roughly speaking, three options can be distinguished:

1. The first solution option comprises the **further development of the grid-based infrastructure - especially district heating**. The expansion and densification of district heating form the backbone of tomorrow's climate-friendly building supply.
2. Another solution option are the **renewable energy sources available within the city for building-specific energy supply**. Wherever heat cannot be supplied by means of heat grids, individual buildings are supplied with energy resources available on site.
3. The third solution option is a **mixture of the first two and combines inner-city energy potentials at building level with a grid-based energy supply**. So-called local heating networks are to be created that supply a neighbourhood or a block of houses with locally available energy.

Instrument 2: Legal framework

In 2020, the federal government and the provinces agreed on a joint framework for decarbonising the heat supply as part of the so-called heating strategy. In numerous working group meetings on various topics, the framework conditions for the transition to a climate-friendly heat supply were discussed. The results led to the draft of the Renewable Heat Act (EWG) as the central legal basis for the topic. This is a federal law that contains precise specifications on when and how the phase-out of fossil fuels in space heating must take place. Subsequently, the federal provinces have to enact the accompanying regulations in the respective material laws and according to the respective enforcement regime, which are necessary in order to be able to effectively implement the requirements of the EWG. In this context, it is particularly challenging that the EWG was not yet in force in 2022 and is still not in force even in January 2023. Only when the EWG has been passed and announced in the National Council can the supplementary provincial laws be enacted. This creates

uncertainties and a certain time pressure, as regulatory measures must be taken in time to be able to achieve the 2040 target. Especially since the exact content of the EWG has not yet been determined, various contingencies must be considered in the best possible way and transitional as well as "emergency solutions" must be worked out.

In connection with the enactment of the necessary provincial regulations, it will first have to be decided in which regulatory regime this should find a place. The current building regulations of the Building Code for Vienna and the Building Technology Regulation already contain far-reaching specifications that guarantee the extensive use of renewable energy sources, also in the area of heat supply, at least for new buildings, additions and conversions or major renovations of a building. As part of the preparatory work for the amendment to the building code planned for 2023, it is currently being examined to what extent these regulations can be tightened in order to contribute to the decarbonisation of the building stock.

Regulations on decarbonisation could find a place in the regime of heating and air-conditioning law or also in a new provincial law yet to be created. For the enforcement of the regulations yet to be enacted, it is indispensable to collect the data that provide precise information on which spaces in Vienna are equipped with fossil fuel heating systems. Thus, in a first step, legal foundations will be created that allow the collection and processing of the data in order to subsequently make it available to the authorities in a database.

It will also be necessary to adapt other substantive federal laws, such as the Gas Industry Act or the various housing laws such as the Condominium Act, the Tenancy Act or the Non-Profit Housing Act. On the one hand, the implementation of energy system conversions must be simplified, and on the other hand, the bearing of costs must be regulated in a fair and socially acceptable manner. The federal government is responsible for legislation in this area. It is therefore important to bring the problems and the need for legal changes in connection with the decarbonisation of the building sector to the attention of the federal government at an early stage and in a consistent manner.

Instrument 3: Affordable housing, subsidies and financing

In order to achieve the decarbonisation of the city of Vienna and our goal of a climate model city, financial investments are indispensable. As a first step, planning and investment security must be created for all affected groups through jointly agreed goals and paths, in order to be able to prepare and plan building projects, coordinations and more as early as possible. Legal adjustments and statements that can be relied on are needed. At the same time, incentives and assistance must also be created that, on the one hand, influence investment and decision-making behaviour in such a way that they are compatible with our climate goals. On the other hand, these aids must cushion and prevent social inequalities and relieve the burden on citizens.

Costs of the heat transition (on the building side)

Approximately 608,000 housing units of use are affected, distributed over about 74,000 buildings. 608,000 utilisation units mean about 34,000 conversions or refurbishments per year. This results in an annual investment volume of almost 1.6 billion € in the next few years. For comparison or classification: 2 billion euros are about 2 % of Vienna's gross

regional product. And as already mentioned, only a part of this 2 billion represents "additional costs" compared to today's business-as-usual, because large amounts are already being invested annually in building renovation and building services. In order for these investments to be implemented in a socially just manner, subsidies are needed, which must be considered in time and communicated to the building owners and residents.

Subsidies for the heat transition

For a socially just implementation, this transformation must be affordable for all Viennese. Accordingly, the subsidies must be further expanded and their accuracy optimised as best as possible. Low-income households not only need financial support, but also information, counselling and guidance throughout the entire process of switching energy carriers. It will also be important to clearly define the roles of tenants and landlords or building owners. The problem of the user-investor dilemma must be taken into account and appropriate solutions found.

What needs to be taken into account in the further development of subsidies?

- Long-term budget planning coordinated with the implementation plan and a related successive increase in the subsidy budgets for thermal renovations and heating conversions.
- Creating possibilities for pre-financing infrastructure expansion in order to reduce the costs for "first-time converters" and to ensure the economic viability of the expansion.
- Additional funding or support for cross-property initiatives (gas-free building blocks or streets) that want to "get out of gas" together.
- There is a need for targeted subsidies with a high degree of social accuracy.
- Better coordination of federal and provincial subsidies
- Further development of funding to include measures relating to the deconstruction of cooking gas.

Instrument 4: Communication, counselling and guidance

The heating transition can only succeed with the broad support of the public, citizens and building and flat owners. It will be the task of the City of Vienna to support and inform the different affected stakeholders with proactive information and communication measures. The combination of information, independent advisory services, subsidies and a pinch of creativity should significantly support the switch to renewable heating and cooling by 2040. This creates planning security - on the one hand for owners, on the other hand also for energy service providers, and the planning principles of energy space planning can be implemented in a coordinated manner across the city.

Consulting for the heat transition

In order to support the process in the best possible way and to make the switch to a renewable heating system as easy as possible, the City of Vienna already offers some assistance and must continuously work on expanding the offers.

Since autumn 2020, citizens who want to make their building or flat fit for the future can contact the "Hauskunft" (a combination of “Haus” (home) and “Auskunft” (advice or information)) for questions on topics such as renovations and heating system switches. It is the central advice centre of the City of Vienna. The services offered by Hauskunft will be continuously expanded and adapted to the needs of city residents in order to provide the best possible support on the way to climate-neutral heating and cooling. This is the only way to jointly achieve the goal by 2040.

The Renewable Energy Competence Centre (“Kompetenzzentrum Erneuerbare Energie”) is the competence centre for all topics related to renewable forms of energy. Here, citizens can also receive counselling. The Renewable Energy Competence Centre will also set up an advice centre for energy communities. Renewable energy communities offer a good opportunity for citizens to jointly generate and consume electricity and heat. For example, a particularly cheap roof area of a multi-apartment building can be used jointly to generate PV electricity, and the electricity is then shared among the residents. These counselling services are complemented by the established format of "Gebietsbetreuung Stadterneuerung", which offers guidance and support on site in the neighbourhoods.

Instrument 5: Labour market and skilled workers

In addition to energy and climate policy goals, Heating and Cooling 2040 will also have a strong stimulus for the Viennese labour market, as in the near future there will be a need for sufficient craftsmen, plumbers, planners, skilled workers, etc. with appropriate quality training for the renovation of buildings and retrofitting of heating systems. This raises the important question of how a rapid energy transition can be achieved from the perspective of the labour market. On the one hand, the ecological transformation offers great opportunities to create additional jobs in Vienna. On the other hand, a lack of skilled workers and resource bottlenecks in the affected sectors jeopardise the implementation of the planned goals.

Within the framework of its environmental and climate policy measures, Vienna always aims to combine these with social policy measures. In particular, long-term strategies, such as the concept Raus aus Gas - Wiener Wärme und Kälte 2040 (Phasing Out Gas – Heating and Cooling Vienna 2040), offer the possibility that people who are currently outside the Viennese labour market can be reintegrated through specific training and further education. In order to obtain reliable data and facts on this very important instrument, a study was commissioned within the framework of the implementation programme in cooperation with the City of Vienna - Economy, Labour and Statistics (MA 23) and the Vienna Employee Promotion Fund (waff).

Within the scope of the study, an analysis of the status quo on the one hand and a needs analysis for the challenges and opportunities for the Viennese labour market on the other hand are to be prepared. The study is to be the basis for the development of economic, social and labour market policy measures and serve as a basis for further transformation processes. The waff's Skilled Workers Centre will play a central role in this.

waff skilled labour centre - focus on "decarbonisation and securing skilled labour"

The programme of the Viennese provincial government stipulates that a strategic labour market instrument - a skilled labour centre for Vienna - is to be established at waff. The most important tasks of the Skilled Workers Centre will include quantitative and qualitative analyses with regard to the demand for skilled workers in Vienna, the development of strategic options for action to solve the problem and the development of effective measures. The Centre for Skilled Workers is therefore not a training centre for skilled workers, but rather a competence centre where problem-solving strategies are developed together with various decision-makers. The aforementioned study should provide an important empirical basis for this. The official establishment of the Centre for Skilled Workers will take place in 2023 with the presentation of the first Skilled Workers Report for Vienna.

A decisive challenge is the identification of potentials for attracting additional workers and especially skilled workers.

The following areas are particularly important for this:

- Young people with regard to their educational and occupational choices.
- The potential of people with a compulsory school certificate or lower, who can be recruited for catching up on educational qualifications and for substantially higher qualification.
- An important group are also the employees of those companies that take on concrete assignments within the framework of the ecological transformation.
- People who currently work in "fossil" industries and whose field of activity will decline have a possible occupational field in professions that deal with renewable energy.
- Foreigners (EU citizens or third-country nationals) who are to be recruited for work activities in the context of the ecological transformation.

Especially with regard to the training of qualified workers, the typically long duration of training must be taken into account. The provision of further training infrastructure also requires lead time. As a result, the necessary training policy interventions must be made at an early stage to secure the supply of skilled labour in the future.

However, Vienna cannot solve the challenges of the labour market alone, as a large part of the responsibility also lies at the federal level. The definition of curricula for vocational schools, the number of places in vocational secondary education - to name just a few points - must be addressed for the whole of Austria. It will be essential to adapt training as quickly as possible to the new needs of the labour market and the challenges of the future. Dealing with renewable energy systems, thermal renovations or the installation of photovoltaic systems can no longer be seen as "add-ons", but must be included in basic training. Tomorrow's skilled workers must also learn to know and apply tomorrow's technologies in the best possible way if the climate goals are to be achieved.

The Road Ahead

The Vienna Heating and Cooling 2040 concept describes the major fields of action that are necessary for Vienna to become a CO_2-neutral climate model city. Of course, a concept alone is not enough to transform a city of millions from a fossil-fuelled to a renewable city. For this reason, the implementation of Vienna Heating and Cooling 2040 was already initiated in 2022 with the programme **"Raus aus Gas"** (RaG, “Phasing Out Gas”) in the City Planning Department.

It is planned to divide this programme into two sections called RaG 1 and RaG 2. By 2025, the foundations identified as such by the concept are to be created so that a broad conversion of Vienna's building stock can be started from 2026.

The RaG 1 programme is strategically managed and coordinated by the Municipal Directorate for Buildings and Technology (Stadtbaudirektion). Numerous municipal departments, companies and enterprises of the City of Vienna are involved in the programme. This broad team is necessary so that the complex challenge of decarbonising the city's energy supply can be dealt with in a holistic manner.

Vienna's energy supply is largely dependent on fossil fuels. Three quarters of the gross domestic consumption come from fossil sources. More than one third of the final energy consumption can be attributed to space heating requirements and thus to buildings. If one takes into account that buildings also require process heat and electricity for electrical building equipment, it becomes clear how important the building sector is for achieving the climate and energy goals. This is where the heat transition comes in. In the future, space heating, hot water, cooling energy and energy for cooking (gas cookers) are to be provided from recyclable and environmentally friendly forms of energy.

In Vienna alone, about 600,000 households currently supplied with fossil fuels will have to be converted in the next 18 years. The majority of these households will be supplied with gas at the household level. A small part is equipped with central gas heating systems and a few tens of thousands of households still use oil heating. If this task is calculated down to daily conversions, it amounts to 100 households every weekday for the next 18 years.

In order to tackle this challenge, intensive work is currently being done to create the necessary foundations for the heat transition. In particular, the legal and subsidy framework must be adapted. In addition, the existing shortage of skilled workers must be counteracted in order to be able to cope with the structural changes. In order to coordinate the tasks of the public sector in connection with the heat transition, the implementation programme Raus aus Gas (Out of Gas) was installed in the Municipal Directorate for Buildings and Technology (Stadtbaudirektion).

For example, the programme is used to specifically **identify the financing requirements** for the heat transition in buildings (especially residential buildings, but also non-residential buildings), but also in the municipal offices.

Strategic public relations and communication will be developed, which on the one hand communicates the plans of the City of Vienna (to achieve the climate goals) and on the other hand supports the acceptance of the measures among the population.

A study will shed light on the areas in which the **labour market needs to be strengthened** in order to be able to draw on sufficient skilled labour.

Further phases are concerned with **optimising the funding landscape** in terms of achieving the goals and adapting the relevant provincial laws.

With the help of **energy planning in existing buildings**, it will be shown in which regions of the city district heating can be expected and where preference will be given to the use of renewable resources available on site.

Within the framework of the programme, **pilot implementations** are to be initiated at Wien Energie, Wiener Wohnen, municipal properties as well as non-profit and private developers and building owners. With the help of these pilot projects, existing technical solution options are to be tested and evaluated in order to finally roll out the most suitable measures to the entire city.

In particular, the initiatives "100 innovative projects phasing out gas" will **explore the needs of buildings of different ages and with different building equipment**. The technical solutions to refurbish buildings in a highly efficient manner and to convert them to sustainable forms of energy exist. The task now is to find out which options are most compatible with economic efficiency and benefits.

With the help of an **effective monitoring system**, the success of the heat transition is to be documented.

The programme interacts intensively with other climate-relevant projects of the City of Vienna, such as the circular economy or urban renewal offensives like Wien Neu+ and WirSanWien.

With the help of the critical success factors of the Raus aus Gas 1 programme, the large-scale rollout in the context of Raus aus Gas 2 (from 2026) will finally be prepared. The rollout will then build on the established foundations of the heat transition and make use of the key findings from the first programme.

DECARB CITY PIPES 2050

Transition Roadmap City of Winterthur

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 893509

Transition Roadmap of Winterthur

Introduction & Context

In 2013, the Winterthur City Council adopted the Municipal Energy Plan Winterthur (Energy Plan 2011).

In the meantime, Stadtwerk Winterthur (the utility) has implemented further district heating networks, continuously increased the connection density in the district heating area, which is supplied with waste heat from the waste incineration plant and announced the withdrawal of the gas supply from the district Gotzenwil by the end of 2026.

At the same time, the overarching climate targets at national, cantonal and municipal level were tightened to net zero CO_2 emissions - Winterthur committed itself to net zero emissions by 2040 in November 2021, while the population of Switzerland only recently voted in favour of climate neutrality by 2050 in a referendum.

Similarly, the revised Energy Law of the Canton of Zurich entered into force in September 2022 and implemented a wide-ranging prohibition of fossil-fuel boilers in buildings.

In view of the greatly changed framework conditions, the Energy Plan 2011 and the roadmap had to be comprehensively revised and supplemented.

The new municipal energy plan was approved by the city parliament on October 31, 2022 and came into force in early 2023

In order to achieve the climate target of net zero tons of CO_2 by 2040, the heat supply of the city of Winterthur will be provided by renewable energies and waste heat.

It is a binding guideline plan that shows in which areas which energy sources are intended for heat supply.

”.

Status Quo

Infrastructure

District Heating: In Winterthur, eight thermal grids are already being operated with a majority of renewable energy sources (three with waste heat from the incineration plant, five with wood).

Gas network: The residential area in Winterthur is largely connected to the gas pipeline network of Stadtwerk Winterthur.

Oil and wood heating: From the chimney sweepers, all gas, oil and wood combustion heatings are registered.

With these and more data, the City of Winterthur's Environmental and Health Protection Department (UGS) publishes an emissions register and a municipal environmental report every four years. This includes the elaboration of an energy balancing and greenhouse gas inventory.

Emissions by sector

The latest balance refers to the year 2020. According to this balance, the heating sector causes around 35% of the CO_2 emissions in Winterthur with 1.5 tonnes of CO_2 equivalents per person and year.

Energy source mix of the heating sector

Fossil fuels (heating oil and natural gas) account for 68% of the heating demand in Winterthur.

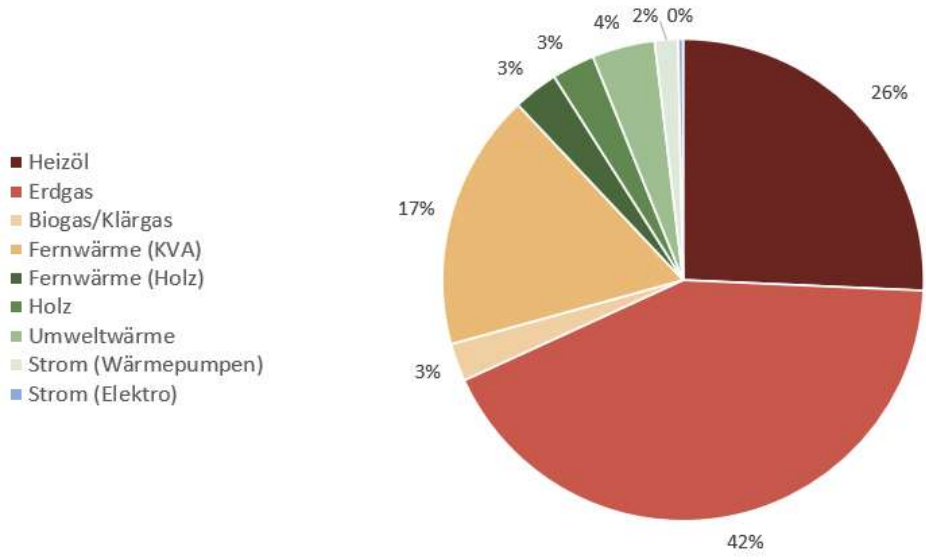


FIGURE 51: ENERGY SOURCE MIX HEATING 2020 (DATA SOURCE: EMISSION REGISTER CITY OF WINTERTHUR 2020)

Goals for 2040 & legal framework

The legal framework and specially the goals to achieve in Winterthur are diverse. The most important include:

2000-Watt Society

In 2012, the Winterthur electorate voted in favour of the 2000-watt society by a clear majority. The 2000-Watt Society is a concept which translates national (and higher) energy and climate goals onto the municipal level, in order to reduce greenhouse gas emissions and the scarcity of renewable energy resources. In 2020, the 2000-Watt society published a new guiding concept with adapted objectives. The following targets apply for the year 2050:

- Energy efficiency (2000 watts of continuous primary energy per person)
- Climate neutrality (zero energy-related greenhouse gas emissions)
- 100% renewable energy supply

Net zero CO_2 emissions by 2040

In the referendum of 28th November 2021, the electorate of the city of Winterthur voted in favour of the net zero target by the year 2040. This means that Winterthur aims to reduce greenhouse gas emissions to net zero tonnes of CO_2 equivalents per year and per capita by 2040 with an interim target of 1.0 tonnes by 2033.

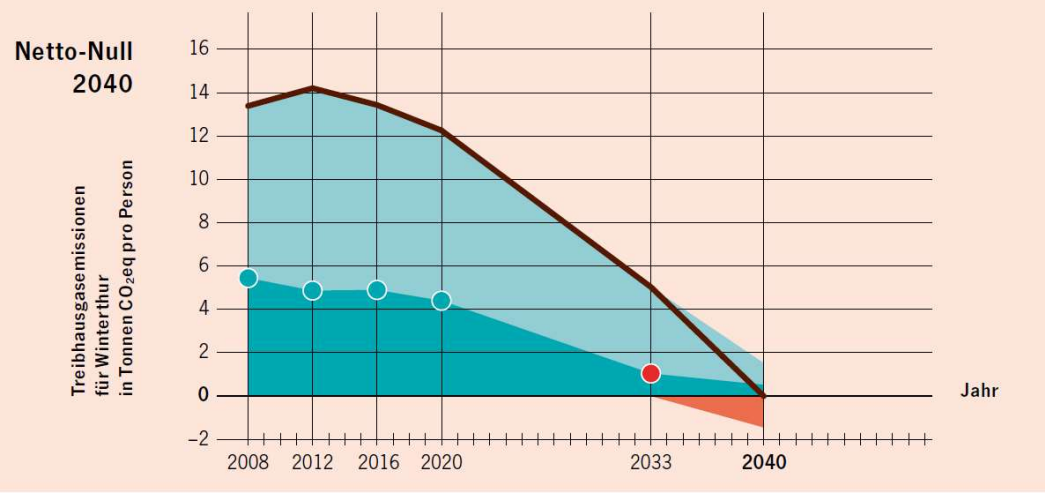


FIGURE 52: ACTUAL AND TARGETED GREENHOUSE GAS EMISSIONS FOR WINTERTHUR IN TONNES OF CO_2 EQUIVALENTS PER CAPITA AND YEAR FOR THE "NET ZERO BY 2040" SCENARIO (SOURCE: EMISSIONS REGISTER CITY OF WINTERTHUR 2020, ENVIRONMENTAL AND HEALTH PROTECTION WINTERTHUR; GREENHOUSE GAS FOOTPRINT, FOEN, SFSO).

Climate and Energy Charter

Furthermore, the Winterthur City Council signed the Climate and Energy Charter of Swiss Cities and Municipalities. Due to the urgent need for action, the city of Winterthur revised the existing energy concept and adopted a climate action plan with 54 climate protection measures.

Energiestadt Energy city (european energy award)

Winterthur has been an energy city since 1999 and was awarded the "European Energy Award Gold" for the fourth time in 2019. The city has thus been pursuing an active energy and climate policy since more than twenty years.

Energy law (cantonal)

The cantonal energy law was revised and adapted to the current state of building technology and entered into force on 1 September 2022. It sets an important course for the reduction of CO_2 emissions in the provision of heat and the increase of energy efficiency. The most important changes are listed below:

- New buildings are to be built according to the state of the art. As little energy as possible should be used for heating, hot water, ventilation and air conditioning (§10a).
- New buildings should be equipped in such a way that part of the required electricity is generated by the building itself (§10c).
- New buildings are to be equipped with heating systems that do not cause any CO_2 emissions from fossil fuels on site (§11 para.1).
- When replacing the heating system in an existing building, only renewable energies (including biogas) may be used, provided that it is economically viable. If the costs for generating heat from renewable energies over the entire life cycle (investment, amortisation, operation and maintenance) are more than 5% higher than with a heating system using fossil fuels, the simplified requirement applies that at least a small proportion of 10% renewable energies must be used or the energy requirement of the building is reduced by 10%. This requirement can be met with a standardised renovation measure (e.g. window replacement) (§11 paras. 2 and 3).
- Existing stationary electric resistance heating systems for heating buildings and existing central electric water heaters are electricity guzzlers and must be replaced by 2035 (§10b para. 3).

Spatial development perspective Canton Zurich

The Spatial development perspective of the canton Zurich defines a priority list of energy sources for heating:

For heat supply, the existing heat sources are to be exhausted and heat networks are to be densified - taking into account economic efficiency as well as supply and operational safety. To this goal, supply areas are to be designated in communal or regional energy plans (H/C-Maps) according to the following priority:

1. **local high-grade waste heat:** In particular, waste heat from waste incineration plants and deep geothermal energy and industrial waste heat available in the long term, which can be directly distributed and used (without need of a heat pump).
2. **local low-value waste heat and environmental heat:** In particular, waste heat from wastewater treatment plants and heat from waters (lake, river, groundwater).
3. **thermal networks:** Densify existing district heating networks.

Outside of district heating networks, the decentralised use of locally unconnected environmental heat from geothermal energy and ambient air as well as the use of solar energy should be preferred for the heat supply; the decentralised use of wood energy should only be considered for the demand for high temperatures.

H/C-Map

Principles

The H/C-Map implements the goals of the city of Winterthur which are mentioned in chapter “Goals”. To remind: For the heating sector, an interim target of 300 kg CO_2-eq per year and person by 2033 is to be applied.

Reduction and transformation path for heating

Based on today's demand, the reduction and transformation path for heat shows how the heat supply is to be redesigned in the coming years (Figure 53).

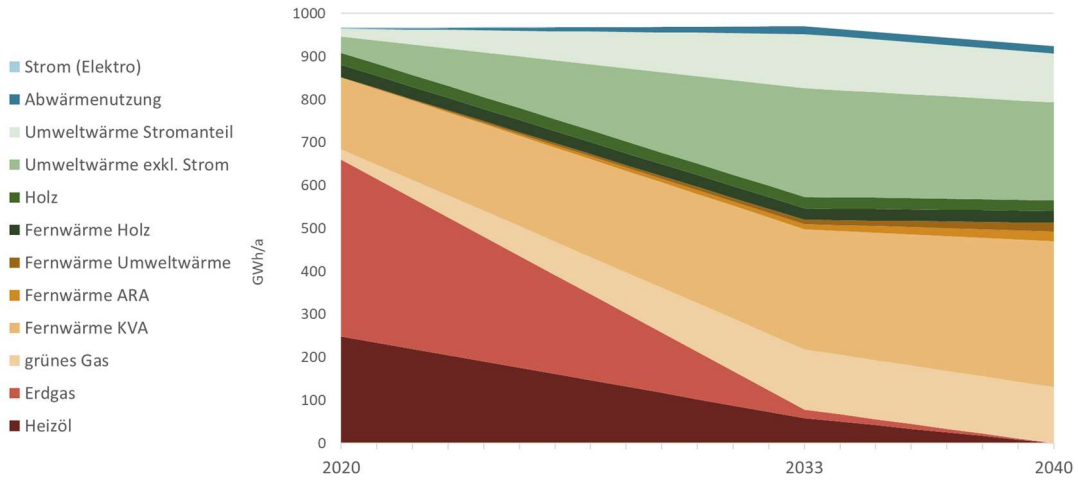


FIGURE 53: REDUCTION PATH FOR HEAT IN THE CITY OF WINTERTHUR (SOURCE: PLANAR 2021)

The target can be achieved by replacing fossil fuels with renewable energies and waste heat (transformation). The availability of renewable energy sources was taken into account. Equally important for the achievement of the target is the reduction of the total heat consumption. The reduction is possible through retrofitting and efficiency improvements. For the estimation of future demand, it has been assumed an annual renovation rate of 1.2%.

As the city is still growing, the reduction is compensated through new buildings (which has to be built in compliance with the goals).

Greenhouse gas target path

The reduction of the heating demand and the transformation of the energy sources have a direct impact on the greenhouse gas emissions. Figure 54 shows the resulting target path of greenhouse gas emissions (t/a) in the heating sector of the city of Winterthur. For the year 2033, the target is met with 0.300 t/CO_2-eq per person. In 2040, a residual emission of 0.101 t/CO_2-eq per person and year remains.

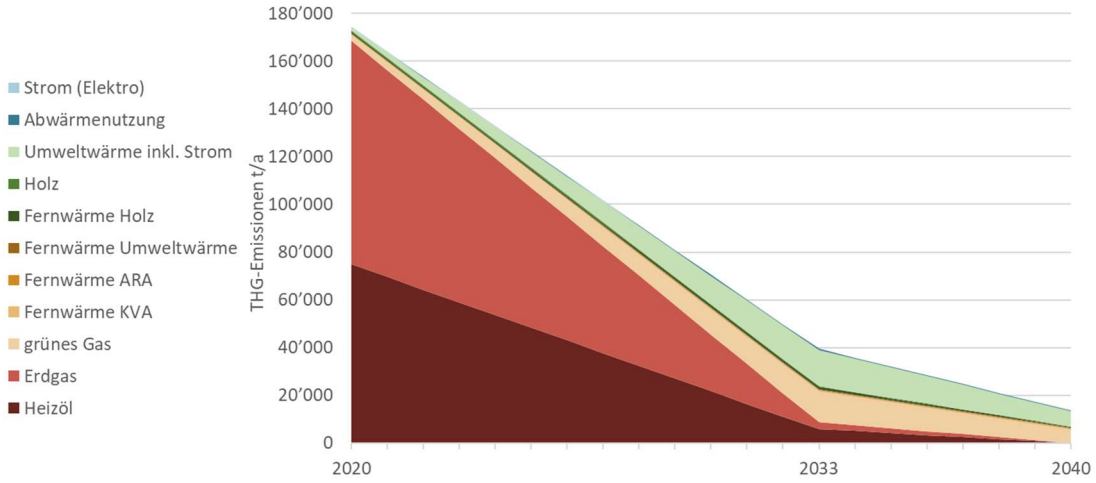


FIGURE 54: TARGET PATH OF CO_2 EMISSIONS IN THE HEATING SECTOR OF THE CITY OF WINTERTHUR (SOURCE: PLANAR 2021).

Despite the conversion to 100 % renewable energies and waste heat utilisation, compensation of the residual emissions through sinks and emission reduction certificates is required to achieve the net zero target. The handling of sinks and emission reduction certificates is discussed in the climate strategy of the city of Winterthur.

Fossil fuels

In order to achieve the communal goal of net zero by 2040, it is necessary to phase out fossil fuels. The requirements for fossil fuels in the cantonal energy law have become stricter.

Strategy for oil-fired heating systems

According to the new energy law of the Canton of Zurich, fossil fuel heating systems may no longer be replaced. The prioritisation in the H/C-Map must be followed when approving replacement heating systems.

Gas strategy

In order for the city of Winterthur to achieve its energy goals, it must switch to renewable gas in the long term. Current estimates of potential assume that 15-30% of current gas sales can be covered by renewable gases in Switzerland as a whole. This means that the gas grid and gas sales must be reduced to a maximum of 30% of the current level (as of Dec. 2021).

From 2040 onwards, gas will no longer be available for space heating, but only for processes in industrial and commercial zones and to cover peak capacity in district heating systems.

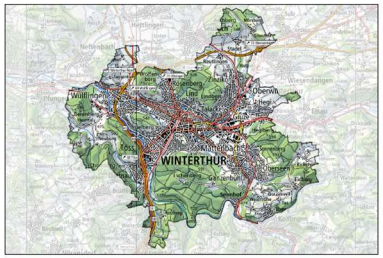
In order to give customers sufficient time to switch their heating systems, the shutdown of the gas supply will be announced at least 10 years in advance, if possible. Moreover, the expansion of the thermal grids will take time in the coming years, so a coordinated, staged withdrawal of gas and the offer of transitional solutions is necessary.

H/C-Map

Stadt Winterthur

Kommunaler Energieplan 2022

Massstab: 1:20'000



Bildquelle: www.swisstopo.admin.ch

PLANAR
RAUMENTWICKLUNG

Projekt:	WIN.24
Datum:	14.04.2022
Format:	840* 594 mm
Erstellt / Geprüft:	GA/ RG
Grundlagen:	Geodaten Stadt Winterthur
Datei:	WIN24_PLA_Energieplankarte.aprx

Genehmigungsinhalt

Verbundgebiete

Erschliessung

- P — bestehendes thermisches Netz
- V — vorgesehenes thermisches Netz

Gasversorgung

Die Gasversorgung bleibt langfristig für Prozessenergie und Spitzendeckung in Verbundgebieten sowie Winterstromproduktion erhalten.
Die reine Raumwärmeversorgung ist nicht mehr vorgesehen, das Gasnetz wird etappiert stillgelegt.
Die Stillegungszeitpunkte ergeben sich aus Übergangsfristen für Anschlüsse an Energieverbunde oder individuelle Lösungen.

Stillegungszeitpunkte:
- Bis Ende 2030: P1
- Bis Ende 2033: alle P-Gebiete und alle E-Gebiete
- Bis Ende 2040: alle V-Gebiete
- Keine Stillegung: ausgewiesene Industriezonen, Spitzendeckungen Wärmeverbunde

Informationsinhalt

Eignungsgebiete

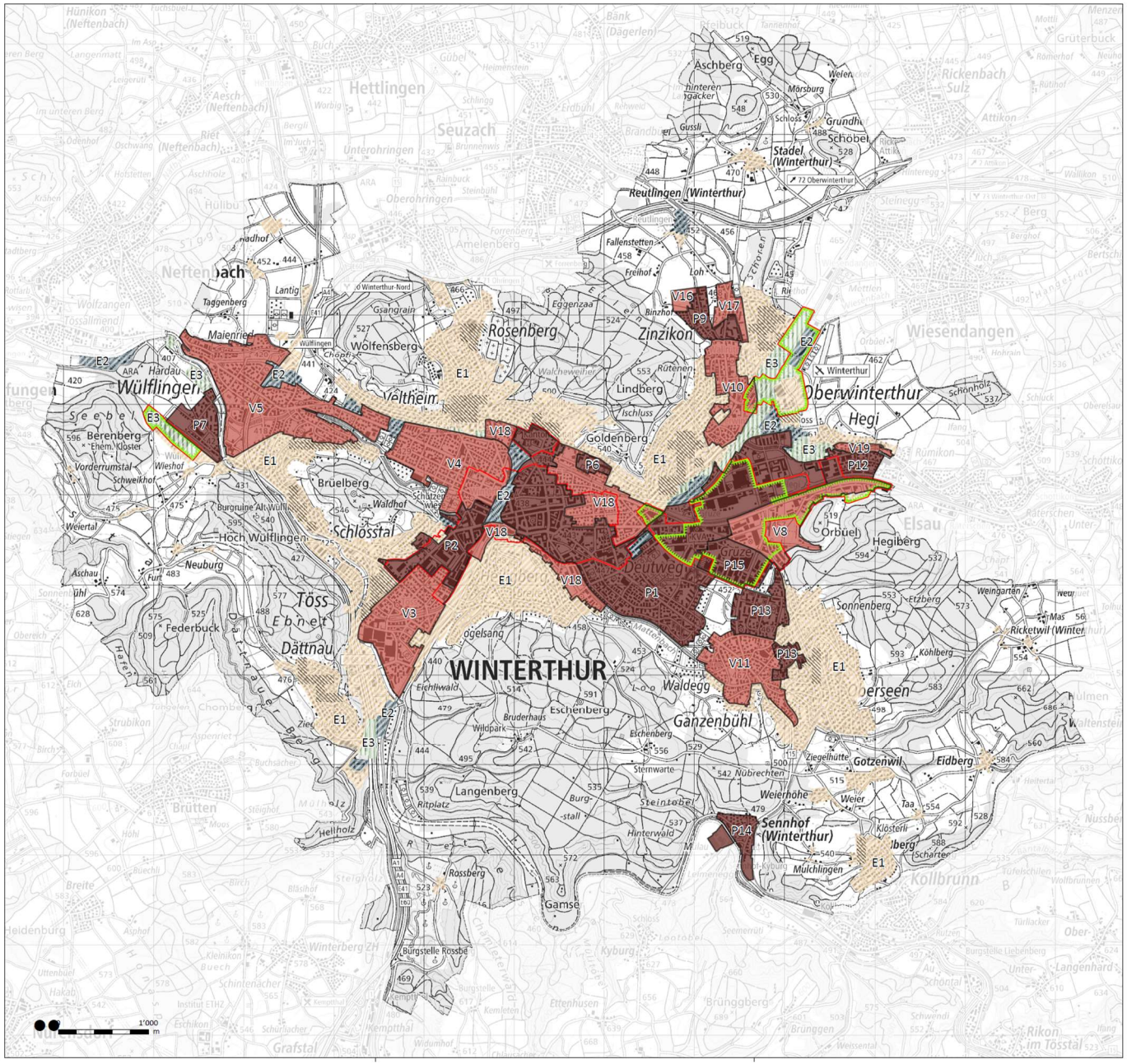
Wärmequellen

- E1 — Erdwärme
- E2 — Grundwasser
- E3 — Umgebungsluft (Luft-Wasser-Wärmepumpe)

Eignungsgebiete werden mit Einzelanlagen oder Kleinverbunden versorgt.
Die Solarstromerzeugung soll in allen Versorgungsgebieten genutzt werden. Die Solarwärme sollte in Verbundgebieten nur in Absprache mit der Energiefachstelle eingesetzt werden.

Zusätzliche Hinweise

- Geeignete Gebiete für Kleinwärmeverbunde
- Industriezonen (Prozessgas verfügbar)
- Gebiete mit potenziellem Kältebedarf



Pathways

The H/C-Map sets the direction for the future heating and cooling supply of the city of Winterthur. In order to achieve the formulated goals, the city's heating and cooling supply must be redesigned according to the energy plan map. The necessary implementation steps are noted in the measure sheets.

The H/C-Map focuses on three different areas which are: "existing thermal network" (P), "planned thermal network" (V) and "areas for individual supply" (E). The designated settlement areas show the desired target state in each case.

Development of the energy source mix

In order to achieve the climate targets, at least 85% of the district heating systems should be based on renewable energies by 2033 and 100% on renewable energies by 2040. Before 2033, the heat in thermal grids must come at least 70% from renewable energies. In concrete terms, this means:

- By 2033, at least 70% renewable
- From 2034 at least 85% renewable
- Between 2034 and 2040 between 85 - 100% renewable energy
- From 2040, 100% renewable (peak coverage fossil-free)

Coupling of thermal networks (District heating systems)

The further development of thermal networks, their coupling and construction of not yet existing district heating systems was the subject of an engineering study. This study considered the following areas as shown in Figure 55 (P1, P2, V3, V4, V11, P13, P15, V18):

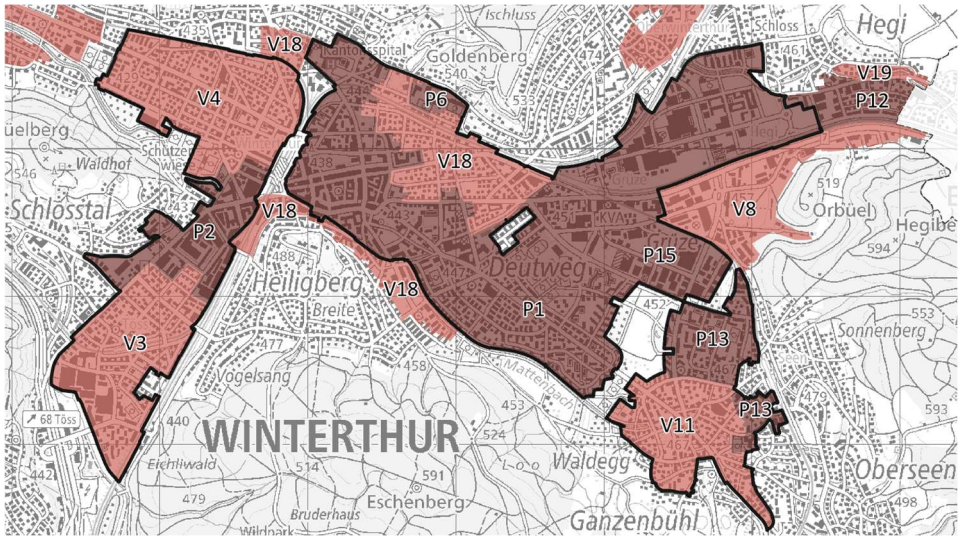


FIGURE 55 : PERIMETER OF THE MASTER PLAN (P1 - V19) AND OF THE STUDY "WÄRMEVERBUNDE UND NETZE" (BLACK BORDER).

The study is to examine the extent to which the P1 distribution network can be enlarged by coupling it with the neighbouring networks in order to supply the neighbouring networks with heat from the incineration plant in summer. In the winter months, the neighbouring thermal

networks are to be supplied by using the local heat potential from "own" heating centres. The incineration plant thus continues to form the core of Winterthur's heat supply.

Conversion phase

In order to be able to accelerate the network expansion, further main pipes are to be laid from the Sulzer-Stadtmitte area (P2) in the direction of Töss-Eichliacker (V3) and Neuwiesen (V4). In the first period, the heat will be provided from the incineration plant heating centre. Additional temporary fossil-fuelled peak capacity boilers will be necessary for this.

The energy source mix can be optimised and the peak coverages reduced, as soon as the individual neighbouring thermal grids have their own heating centres.

The temporary deterioration of the energy source mix is accepted in favour of a rapid grid expansion and earlier climate neutrality. It can also be assumed that, despite everything, there is a positive overall benefit if the replacement of purely fossil-fuelled decentralised heating systems necessitates greater fossil-fuel peak capacity in the P1, because more waste heat and renewable energies can be used overall.

Individual supply

In Areas with individual supply (E), the strategy is given through the energy law of the Canton Zurich, as fossil heating must be replaced by a renewable solution (see also Chapter Goals – Energy law).

Roadmap

Measures to be implemented

To reach the goals and to implement the H/C-Map, there are several measures foreseen. For each area shown on the map there exists an own sheet on which the measure is explained. Furthermore, the responsibility is fixed, and a timetable shows the next steps to be taken and by when (see also Appendix).

Additional there are six supporting measures defined. Five from them are shown in the following paragraphs. The sixth is to order a new study about the deep geothermal potential in Winterthur.

1) Engineering Study

The engineering study to couple the thermal networks is already in progress. The aim is to maintain a flexible infrastructure that can be used optimally. Details on the coupling have been explained in the previous chapter.

2) Organisation and resource building

In order to achieve the objectives of the city of Winterthur and to implement the H/C-Map, a lot more thermal network pipes and connections will have to be built in the next few years than in previous years.

The central implementation organisation of the H/C-Map is the utility “Stadtwerk Winterthur”. In order for the implementation to succeed, Stadtwerk Winterthur needs the support of the City of Winterthur, in particular of the building department, but also of other municipal offices. They all need sufficient resources (human and financial).

Structural/organisational

In order to make this rapid expansion possible, a number of framework conditions need to be created:

For this, three working groups will be established:

Working group on acceleration measures for heating networks

(Head: City Councillor, involvement of Head of Stadtwerk Winterthur, Head of environmental and health department, Head of Civil Engineering, Energy Department). Start: September 2021

Tasks:

- Identify and remove structural/organisational obstacles.
- Increase the speed of administrative processes in the administration, either by simplifying processes or increasing resources.
- Optimise interdepartmental construction coordination and cooperation.

Working group on master plan for heating networks

(Head: Stadtwerk Winterthur, including the head of environmental and health department and the Energy Department as well as the Civil Engineering Office)

Start: December 2021

Tasks:

- Preparation of the master plan, which aims to implement the energy plan (cf. M1).
- Rough network structure (main pipes / temperature level)
- Concept for heat generation
- Locations for heating centres
- Timetable

Working group for monitoring the implementation of the energy plan

(Head: Energy Office, involvement of Stadtwerk Winterthur, Head of environmental and health department).

Start: January 2022

Tasks:

- Annual monitoring of progress in implementing the Energy Plan (cf. M5)
- if necessary: Definition of corrective measures

Result: A yearly short report in KUE

Resources

Stadtwerk Winterthur and the other administrative departments - in particular the Civil Engineering Office - determine the human and financial resources required to implement the H/C-Map. If changes in the organisational structure are necessary for an optimal implementation of the H/C-Map, these must be taken into account accordingly.

Subsequently, the corresponding resources are to be approved by the city council as well as by the city parliament and the people. It is likely that one or more referendums will be required. This can take place at the earliest after the master plan has been presented.

3) Information, Energy Counselling und Subsidy Schemes

Information to customers and land owners should be internally coordinated and consistent.

When the energy plan comes into force, the property owners are to be informed on an area-specific basis about the gas supply and the planned expansion of thermal grids.

Periodic, targeted information campaigns should support the transition and increase the rate of energy-related renovations.

Development of a "building-specific" energy cadastre plan in geographic information system (GIS), also as a tool for public relations work.

4) Controlling

Controlling is carried out by means of an implementation control and an impact control.

In the implementation control, the progress of the different projects is checked with the help of the measure sheets (See Annex). It should be carried out at least once a year by the Implementation Control Working Group.

The impact monitoring records the extent to which the measures already implemented have an impact on the greenhouse gas emissions caused by the heating sector on the city's territory (the grey energy of the piping and central building is included in the calculation via the greenhouse gas emission factors).

The controls are carried out periodically (survey annually or every two years). For this purpose, a selection of suitable indicators is to be made: For a simple annual review of the progress of the work, never-threshold indicators are suitable, such as number of oil and gas heating systems, newly constructed km of heat pipe, number of new connections to thermal networks etc.

For a more in-depth review (every two or four years), indicators that are collected as part of the preparation of the energy and climate balance (or emissions register) of the environmental and health department are suitable. Up to now, this has been done every four years.

5) Transitional solution

Many buildings are still heated with oil and gas today. Oil and gas heating systems must be replaced by climate-neutral heating systems at the end of their life. When a heating system is due to be replaced, many property owners are therefore faced with the question of an alternative solution. A central role is played by the planned thermal networks that will be built or further expanded in the coming years.

Without a network solution, they decide for an individual solution. If there are too many individual solutions, the district heating can’t be operated economically. Until the corresponding connections are available everywhere, building owners have to be offered a temporary transitional solution by the energy service provider and the Energy Office.

Appendix:
Example of measure sheet

Nr. Titel			
Last Trackings	11.01.2022, PLANAR		
Status of implementation	Proceeds according to plan	remarks:	
Objective			
Current energy source			
Temporary solution			
Energy sources to be taken in account	☒ waste heat incineration plant ☐ waste heat sewage water treatment plant ☒ waste heat from Industry or Cooling ☒ Thermal groundwater utilisation ☐ Geothermal energy (possibly also as seasonal storage) ☐ Heat utilisation River Töss ☐ Firing systems with wood and waste heat from CHP with biomass ☐ thermal solar energy ☐ Ambient air		
Cessation of gas supply	☐ no grid available ☐ End of 2030 ☐ End of 2033 ☒ End of 2040		
Initial situation			
Description of measures			
Project responsibility			
Procedure	Steps	Lead (Involved)	Deadline
Interfaces, Conflicting goals			
Risks, Challenges			
Documents			
Enforcement Journal	To be continued…		

DECARB CITY PIPES 2050

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 893509