Recommendations for Cities' H/C Supply & Demand in 2050

Deliverable 2.7

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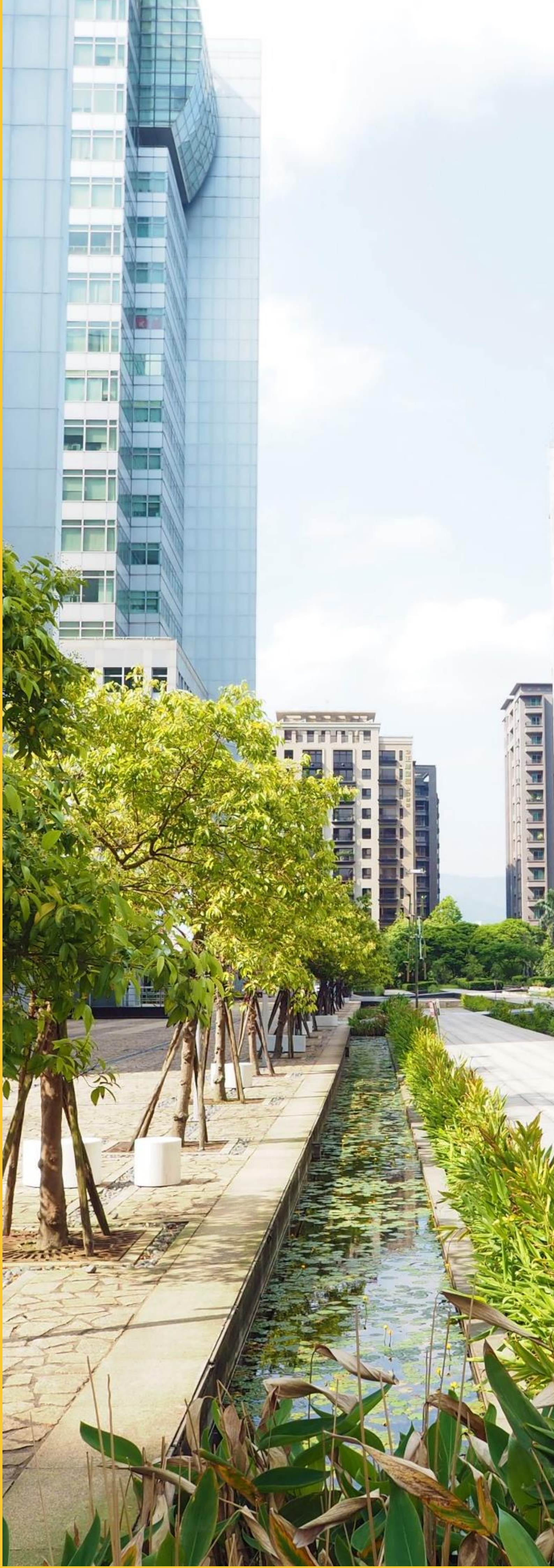

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Introduction

This report provides a set of recommendations that cities can follow when taking stock of their current heating and cooling supply and demand and looking ahead to a targeted heating system in the year 2050 (or earlier).

Such an inventory, and in particular a target picture derived from it (= Heating and Cooling Outlook), has also been made by the project partner cities in the framework of the *Decarb City Pipes 2050* project. Creating such a heating and cooling outlook was the first major step, cities underwent in their pursuit of full decarbonisation of their heating system. Based on these outlooks, spatially-differentiated heating and cooling plans and transition roadmaps have then been created to further outline the path towards a climate-neutral heating and cooling in buildings.

The experiences and lessons learned during the process of this first major step of building up a heating and cooling outlook – so getting to know the WHAT needs to be achieved? - have been gathered, synthesized and processed in form of easy to understand recommendations. These reflect each city's outlooks, highlight criteria and approaches used and discuss pros and cons of different aspects of evaluating energy carriers, sources, demands etc.

In addition, the recommendations build on a methodological framework developed by Halmstad University and the City of Vienna, which was used to define concepts for decarbonizing heating and cooling in cities based on urban typologies. The typologies are summarized in the last chapter of this document. More detailed information on this methodological framework and city-specific examples for the partner city case can be found in the report on "H/C Outlook 2050 of cities with cross-city synthesis" (D2.6[1]) and "Decarbonisation design-approaches based on urban typologies" (D2.5[2]).

[1] H/C Outlook 2050 of Cities with Cross-City Synthesis (D2.6) 2022: https://decarbcitypipes2050.eu/wp-content/uploads/2023/06/DCP-2050_D2_6_Final-version-for-submission-Edited-version_221213.pdf

[2] Decarbonisation design-approaches based on urban typologies (D2.5) 2022: https://decarbcitypipes2050.eu/wp-content/uploads/2023/06/DCP-2050_D2_5_220916.pdf

Step-By-Step Towards Decarbonising a City's Heating and Cooling System

The main intention of the three-year Horizon 2020 project *Decarb City Pipes 2050*, was to break down this enormous task of achieving the urban heat transformation into small, achievable steps, whilst ensuring a beneficial environment for cities to learn and gain from each other´s experiences. As seen in Figure 1, three steps were identified. With each step the level of details gathered and processed increased.

Figure 1: Methodology of Decarb City Pipes 2050:
From H/C Outlook (What?) to H/C Plans (Where?) to Transition Roadmaps (When & How?)
Source: Energy Cities / Project website

Having a long-term vision is key!

Given that having a long-term vision for the future heating system that is agreed upon and accepted among relevant local stakeholders is of such fundamental value, cities - as a first step in the project, spurred discussions on what their urban heating and cooling system could and should look like by 2050 (at the latest). To this end, the cities have provided a quantitative breakdown of which energy carriers and sources will power the future decarbonized urban heating and cooling system - and which most likely will not. The forecasts made also included expectations about future population trends, renovation rates, CO_2 emission targets, etc. The cities also agreed on basic principles that are relevant for future energy and urban planning.

The heating and cooling forecasts were elaborated in **local working groups**, which were (re-)established in each city at the beginning of the project. These local working groups each comprised all relevant local stakeholders required for the energy transition, such as several municipal departments, energy suppliers and grid operators, housing associations etc.

In a next step, the project cities had to translate these quantitative heating and cooling outlooks to the spatial level and describe in detail the spatial distribution of specific heating and cooling solutions. These heating and cooling plans were completed in March 2022 and published in the report "H/C plans of cities with cross-city synthesis" (D3.3[3]).

At the time of this reporting, cities are close to completing the development of transition roadmaps detailing how the heat transition will be implemented by 2050 at the latest - what measures will be defined, what tools will be used etc. These roadmaps will be uploaded soon also to the project website: https://decarbcitypipes2050.eu/

What is (the use of) a H/C Outlook?

The H/C outlook is a forecast for future energy demand and supply for 2050, with the purpose of serving as an agreed starting point and a compass for the next steps (to decide on WHERE: techno-economic spatially H/C plans and HOW&WHEN: transition roadmaps). These outlooks help cities and all stakeholders to set both a clear goal as well as boundaries on what is possible and what is not.

This first step is not about details, but about setting the scene. It shows the impact of trends on supply and demand and helps give direction to the energy transition.

Recommendations

The following recommendations were drafted based on the cities' experience in creating their own heating and cooling outlooks. Firstly, it will be explained how these outlooks have been prepared by the cities. Subsequently, the cities' approaches towards evaluating and estimating current and future energy demand and supply are presented, broken down by energy sources and carriers. In these chapters we will also address the question of which heat sources and carriers should be prioritized and to what extent. Furthermore, recommendations on the topic of data are given.

Lastly, the concluding chapter outlines an urban typology-specific approach created as part of the project that can be applied when bringing the objectives set forth in the H/C Outlook to the spatial level.

First: Ensure Stakeholder Involvement!

Cities represent a good platform to bring together different stakeholders needed to critically advance the decarbonization process at the local level.

During this first step of analysing future (potential) supply and demand it is important to have those stakeholders that can give valuable input for an overall view. The local

[3] Decarb City Pipes 2050 (2022): Cross-City Summary of Heating and Cooling Plans (D3.3): https://decarbcitypipes2050.eu/wp-content/uploads/2022/09/D3.3.-Cross-city-summary-HC-plans.pdf.

working groups – introduced in this project - formed in each city at the beginning of the project included all stakeholders relevant to the topic precisely for this purpose, e.g. municipal departments, energy suppliers, grid operators, housing associations etc. The composition of these local working groups varied according to local conditions and in some cases included several levels (local, regional as well as in some cases national level). In these groups, manifold aspects regarding the heat transition were discussed on local level at regular intervals. At the beginning, there was a discussion and a consecutive agreement on a common vision and central and essential principles that are to be applied in the design of the future heat transition. In the best-case scenario, this vision was then also approved by the city's politicians.

It is important to find out at the beginning which urban stakeholders must be brought on board and with which actors a good and regular exchange should take place. But note: The depth of stakeholder involvement will increase along the way.

Later in the process, while making H/C plans, the home owners play a bigger role. In the end, it is going to be their buildings that need to be transformed and these costs need to be part of the planning. In the last step, all citizens, owners as well as residents, need to be involved. It is a balancing act to involve different stakeholders just in time. Too early, and they cannot contribute actively and feel lost. They will most likely stop participating. Too late, and the stakeholders do not feel taken seriously and can also be lost for the process.

Thus, thinking about stakeholder involvement during this very first step is crucial. An open communication on who to involve and why, opens up discussion and enables cities to adjust the approaches based on the input they receive.

How to Build Up a H/C Outlook?

For building a H/C outlook there are several steps that may be taken:

1. Analyse Current Situation
2. Estimate Future H/C Demand
3. Estimate Future H/C Supply
4. Define Core Principles For A Future H/C System
5. Get The Right Data
6. Use Typologies

Each step will be addressed in the following.

1. Analyse Current Situation

In order to determine what the heating and cooling sector should or could look like in the future, a comprehensive status quo analysis and, based on this, an assessment of the problem was first carried out. For this purpose, e.g. the city of Vienna first made an

overview of how many greenhouse gas emissions were attributed to which sector[4].

The city then also broke down its **final energy consumption** (roughly 50% were attributed to heat: space heating, hot water and process heat in production) and consequently its **heat consumption** into space heating (responsible for almost 2/3), cooking and hot water (less than 20%). In turn, it was shown that only a small part of their final energy demand was attributed to many different **industrial (high-temperature) processes**.

In addition to current consumption, the current **energy carriers used** to meet demand were determined:

- In 2018 in Vienna, roughly 40% of the heating demand in buildings were covered by fossil gas and district heating respectively. A small part of the demand was being covered by electricity, oil and biomass. District heating, in turn, is covered by nearly 57% by cogeneration plants running on gas, 20% by waste incineration, and 14% by biomass combustion.
- In Rotterdam, fossil gas covered around three quarter of Rotterdam's heat supply, while heating networks supplied a bit less than one quarter.
- In Dublin, 74% of dwellings were sourced on gas, 18% electric (direct electric, mainly, not heat pumps), 7% on oil.

Gas is in the case of all project cities still by far the most important energy source, e.g. in Vienna covering almost half of the city's final energy demand[5].

An **analysis of the building stock** yielded for Vienna that non-refurbished multi-family homes with individual gas boilers were by far the leading type of buildings (around 306,000 buildings). Furthermore, of the currently approximately 600,000 units (residential flats and non-residential units like offices) with gas heating in Vienna, approximately 475,000 were decentralised gas boilers (located in individual flats). In addition, there are about 460,000 cooking gas appliances in Vienna's building stock that also require conversion measures. In turn, new buildings make up only a small part of the building stock in Vienna.

Furthermore, currently **available infrastructure and recent developments** were analysed by cities. For example, in Rotterdam, a high-temperature, semi-publicly owned DH network has been in place since the 1950, in the beginning supplied by a gas CHP, later on connected to waste heat from a waste incinerator. In the last centuries, few new district heating systems were built and expanded using combined heat and power systems (CHP) on natural gas and the main waste incinerator. Currently there are, however, very little low-temperature heat networks. In Dublin, with a total length of 5,692 km, the gas network (more than half of it for the provision of low-pressure gas) covers

[4] In the case of Vienna, around 30% of emissions in 2018 were attributable to heating, cooling and hot water production. In turn, around 90% of these emissions are attributable to heating gas. Around 600,000 gas boilers are currently installed in Viennese residential units, which currently run on fossil gas.

[5] In Vienna, nearly 2/3 of gas are used for generating electricity and district heating, while around 1/3 is used for heating, cooling and hot water generation. Less than 10% are, in turn, used for process heat.

almost the whole city. The network was developed at national level by semi-state-owned companies, who back then did not consider if DH grids may be a better option.

2. Estimate Future H/C Demand

Once the current status quo of energy demand is known, it is necessary to estimate how much heating and cooling will be needed by 2050. There are many studies and analyses available, that will help cities to assess the long-term development of the heating and cooling demand as well as the supply potential. Halmstad University, presented in the context of the project a summary and analysis of existing scenario studies and other relevant information, like for example, the projections of heating and cooling degree days (see Figure 2[6]), showing the increase of cold demand especially for the southern countries and the decrease of heat demand.

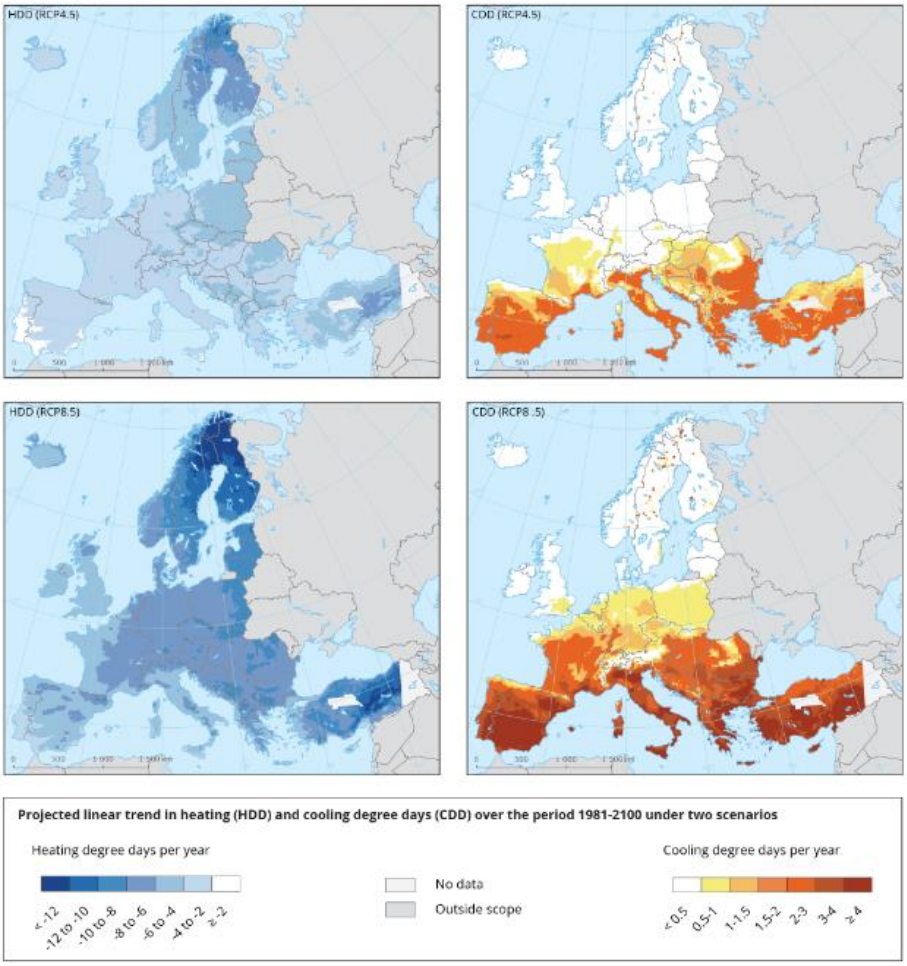

Figure 2: Projections of heating and cooling degree days (Source: EEA 2019)

The H/C outlooks should relate to (if already available) targets within city-accorded strategies[7] and policies regarding climate neutrality, energy efficiency, heating and cooling supply and hot water, and renewable production.

Rotterdam for instance, aims to achieve climate-neutrality and, most specifically, natural-gas-free heating by 2050. Vienna, in turn, targets 2040 for reaching climate

6 Source: EEA 2019. Projected linear trend in heating (HDD) and cooling degree days (CDD) over the period 1981-2100 under two scenarios (based on Spinoniet al. (2017), doi:10.1002/joc.5362, Figure 5). European Environment Agency, Copenhagen. Available at (2020-09-07) https://www.eea.europa.eu/data-and-maps/figures/projected-linear-trend-in-heating

7 The first basis for Vienna's H/C Outlook was its Smart City Wien Framework Strategy from 2019, which defined, among other things, targets for 2030 and 2050 and pathways for heating and cooling as well as hot water, and for RES production. These targets were revised with the government agreement 2020. For heating and cooling, these new targets implied a complete phase-out of coal, oil and gas until 2040. Subsequently, the H/C Outlook was adjusted to the 2040 climate neutrality target.

neutrality. For heating and cooling this implies a complete phase-out of coal, oil and gas needs to be achieved until 2040. For more details on and a summary of current legislative framework situations of the partner cities as well as policy recommendations, see D6.1 Policy Recommendations[8].

In order to estimate future H/C demand and consequently build up an energy plan, Munich used estimations, calculations and figures on the following aspects as baseline information:

- Heat density
- Heat consumption of buildings (differentiated between residential and commercial buildings)
- Final energy consumption
- Heated buildings

Energy Efficiency And Refurbishment Rate

All partner cities consider reducing demand for heating as an important part of the heat transition, not the least because renewable heat sources often do not equal current demand. And the lower the temperature demand, the more energy sources become available. However, only well-insulated buildings can be sourced with lower temperatures. The remits of an area covered by district heating are also defined by the amount of energy source it is powered by and by the heat demand in the area respectively. The reduction of heat demand through energy efficiency measures and the pushing for renovation measures can increase the area that can be supplied with district heating.

Thus, most cities have decided to aim for an increased renovation rate, and to follow the Energy Efficiency First principle - a kWh not used being the best one. For example, Vienna's city-wide targets specify an annual reduction in final energy demand of minus 1 percent per capita and year. Despite the long-term effect of climate change and the fact that an ever-increasing share of new buildings (with low energy demand) reduce the per capita consumption, this goal still requires a substantial increase in the annual renovation rate. Also, Rotterdam expects its future total heating demand to decrease due to energy savings, i.e. through insulation and refurbishments, which will also lead to increased living comfort and the possibility of more efficient use of heat sources and heat networks.

Whether a house is refurbished or not often determines what kind of heating solution would be technologically and economically feasible. Combining the spatial distribution of refurbishments (e.g. through spatially disaggregated funding) with changes in the heating system (e.g. connection to a district heating system or, if not possible, heat pumps) would bring economic advantages. However, a connection to a district heating

[8] D6.1 Policy Recommendations to improve the regulatory framework 2023: https://decarbcitypipes2050.eu/wp-content/uploads/2023/06/DCP2050_D6.1_Policy-Recommendations.pdf

system does often not require a refurbishment at all, if a high temperature heat source is available.

Given current and also expected refurbishment rates, it will definitely not be possible to have as many refurbishments as heating exchanges required.

Analysing Heat and Cooling Density

An analysis of heat density is also essential when considering the demand side. Ultimately, dense neighbourhoods and areas could be supplied with different heat carriers. Most project cities strongly consider the expansion of district heating in densely populated areas (see also chapter on “Define Core Principles” as well as D3.3 H/C Plans of City and Cross-City Synthesis[9]). This first analysis of heat density is also used in the second step (to define the WHERE), when elaborating H/C plans for a city.

Future Cooling Demand

One topic that will increasingly affect many cities due to climate change and rising temperatures, but is often insufficiently taken into account, is cooling. Project partners have also carried out – to a varying extent - analyses and forecasts of how future cooling requirements will develop.

Some cities considered further expanding district cooling networks (e.g. Vienna and Munich). Bilbao used its heating and cooling ratio to decide in which places the use of heat pumps would be preferred. Winterthur analysed its cooling demand by regarding the data about industry affiliation from company statistics.

The city of Rotterdam estimates that cooling demand for existing and calculated new buildings in 2050 will be 47 percent higher for residential buildings and 5 percent higher for non-residential buildings than in 2020, but also stated that it is difficult to estimate the amount of cooling demand at this time because of the unknown scope of temperature increases.

However, since heating demand is likely to continue to outpace cooling demand in most cities in the coming decades, this aspect has been given a lower priority than the heating sector in all cities.

Furthermore, tackling the cooling demand is not just a matter of installing cooling installations. The biggest win is preventing the cooling demand, in the buildings e.g. through installing shading constructions and green roofs and by preventing heat island effects through smart urban planning, e.g. by using green and water to naturally cool the city.

[9] D3.3 H/C Plans of Cities and Cross-City Synthesis: https://decarbcitypipes2050.eu/wp-content/uploads/2022/09/D3.3.-Cross-city-summary-HC-plans.pdf

3. Estimate Future H/C Supply

Once demand is estimated, it is time to match it with the supply side. These steps can also be taken in parallel or in an iterative way. A core element of an H/C Outlook concerns the approximate determination of which heat carriers or heat sources can or should be used in the future or as a priority. In the following, the respective urban approaches are summarized and corresponding recommendations made.

Energy Sources

Many cities have a variety of potential renewable heat sources to draw upon. Rotterdam's energy source strategy takes into account that potential for waste heat, geothermal heat and aqua thermal heat is bigger than the foreseen future demand.

Geothermal Energy

All cities except for Bilbao looked at the potential of deep geothermal energy. For example, Munich is in the advantageous position of being able to draw from massive geothermal potential in the close proximity of the city and has already successfully achieved the integration in its DH system. The city calculated that 80% of the future heat demand in the current district heating system can by covered by geothermal heat. Other cities are currently testing and will try to harness potential geothermal energy, for example Vienna will start drilling in 2024. For a successful business case, it is viable to have enough heat demand. This, however, makes the process – especially when it comes to elaborating a Transition Roadmap the details on the HOW and WHEN - more complex.

Geological data gives insights on the potential of geothermal heat. Additional research in form of boreholes is, however, often needed. Since boreholes need an adequate amount of area, they should be integrated in the cities' spatial planning at an early stage.

Seasonal storage can – if possible - potentially improve the efficiency of a geothermal source.

All cities also took into account heat pumps drawing on near-surface geothermal heat. Bilbao, for instance, considers a low-temperature geothermal network for its new-to-be-built area Zorrotzaurre.

Waste And Residual Heat

With companies and industry most often being situated still in or near city locations, many cities have the advantage of lots of waste heat potential, which might be harnessed at different temperature levels. Dublin for example is striving to build a DH network largely based on the waste heat of data centres. In Rotterdam, industrial residual heat (from waste, electrolysis and industrial processes) has great potential for supplying energy to the heating network. The city even expects heat supply to exceed heat demand by large (close to a factor 2). At this moment about 120 PJ of heat is wasted by the industry. By 2050 the aim is only to use waste heat without fossil origin, still the estimates are that through industrial waste heat and geothermal energy with a small share of solar-thermal energy, it will match the demand of the bigger Rotterdam The Hague region of 40 PJ. In turn, however, it expects a shortage of CO_2-free electricity, as will be the case for all sorts of green gas.

However, when drawing on this source one needs to ensure long-lasting and constant usage of the available heat (e.g. through contracts).

Electricity (Wind/Sun/Water)

Switching to zero-carbon heating sources will most likely also include using electricity from renewable sources, to heat buildings instead of fossil fuels like natural gas. The amount of electricity needed will increase rapidly over the next couple of years, with sectors like mobility most likely to shift towards its heavy usage. Therefore, cities should give top priority to opportunities to leverage on-site PV potentials, as well as wind and hydropower potentials where appropriate.

All partner cities consider the promotion of heat pumps alongside district heating as key for decarbonizing heating and cooling in cities:

- In regards to cities energy zoning and heat plans, heat pumps (as stand-alone solutions) are being considered as THE tool of choice especially in less dense areas or in new buildings where district heating is not economically viable.
- Large-scale heat pumps are seen as crucial to decarbonizing district heating, which until now has been predominantly fossil-fuel-generated in most cities in case already existing.

There are different types of heat pumps: the ones using air, ground water or even heat and cold storages underground. Using ground water or heat and cold storage is more effective than air–water heat pumps, but it is not always possible to install.

While new buildings are already frequently equipped with heat pumps, heat pumps in existing buildings are not yet a very common solution. Current barriers cited by cities include high initial investment costs and a general lack of knowledge, expertise, and capacity in installing heat pumps.

All Decarb City Pipes 2050 cities unanimously recommend to remove regulatory and financial barriers for (large-scale) heat pumps as far as possible in order to support a rapid implementation in case of heat system changes.

Biomass

Biomass has been given only secondary consideration by many cities. Due to the lack of availability of a sufficient source near cities, as well as aspects such as air pollution, biomass is assigned a rather limited role by many cities regarding the production of low-temperature heat, most especially since this type of energy source is a “high value” energy source, as is hydrogen and methane.

The use, as described below – and only if no alternative is available -, should be limited to ”high value” energy use, such as balancing the energy system and (industrial) processes.

Hydrogen & Methane

Green gases like hydrogen and methane promise solutions for high-temperature usages. Future limited availabilities would however strongly advise against using those green gases for low-temperature or space heating purposes respectively.

While sustainable gases – such as hydrogen and biogas – can also serve as fuel for heat, their availability will be limited in the short and medium term, and high prices will not make them a viable alternative to natural gas for heating homes. Thus, all of the cities assume that there is not going to be enough green gas to replace natural gas in full.

In most cities, like Rotterdam, Vienna, Munich etc. these “high value” energy sources are preferred for specific industrial processes (as feedstock or for high-temperature heat generation), energy storage, and electricity and district heat production during very cold peak demand periods, and maybe some heavy and long-distance transport when alternatives are lacking.

Indirectly, the combustion of sustainable gases in industry nevertheless generates residual heat for heating networks. And the production of hydrogen (electrolysers) also produces heat, which can then in turn be harnessed again.

Energy Carriers

The type of sources that will be used, give direction to the type of energy carrier needed.

District Heating

All Decarb City Pipes 2050 cities plan to strongly push for green district heating systems for their future energy supply. Most partner cities pursue the ambitious expansion of their district heating system, which most cities, except for Dublin and Bilbao, already have at least to some extent in place. Munich, for instance, wants to connect more than 20,000 buildings to its DH by 2030.

Most DH systems are, however, currently still primarily fuelled by fossil fuels. Decarbonising the district heating system is thus of utmost priority also in most cities. Most energy utilities are well advised to address this sooner rather than later, since plants for electricity and heat generation above 20 MW fall under the EU Emission Trading System. Thus, these plants will have to transform to become more sustainable. However, that might end in having less and/or lower temperature heating.

But what sources should and could be harnessed to power a district heating network (see also chapter on “Energy Sources”)? For instance, Munich and Vienna are ambitiously pushing for geothermal energy. Rotterdam wants to make use of the ambient heat of the harbour combined with geothermal heat. Dublin expects to integrate waste heat from data centres as a main source to build up their DH system from scratch.

In the event of a corresponding drop in demand within an entire building, because the required supply temperatures are lowered due to thermal renovation, a reduction in the temperatures in the district heating network can also be considered. Depending on the demand side / the energy efficiency of the houses to be supplied by district heating, one might think on the option of lowering temperature in the DH system or using the return flow.

Electricity grid

All project cities see large potential in the use of heat pumps, most especially in less densely populated areas with less heat demand density, in which the expansion of district heating is economically not feasible.

With the increased use of heat pumps (as well as due to increasing amounts of PV systems and (fast-)charging stations for e-mobility, however, the capacity of the electricity grid also needs to be taken into account. The electrification of the heat demand can overload the current electricity grid, this is e.g. expected in some parts of the Netherlands.

Munich like many other cities consider small district heating networks and heat pumps to be the most suitable supply options outside the main district heating network. Analyses of hydrogeologists showed that the depth of ground water allows the use of decentralised ground water heat pumps in most areas outside the district heating network. In this case a district heating network is still needed. It will, however, probably have less impact on the electricity grid.

Gas grid

The partner cities assume that an expected and planned increase in heat pump installations as well as the expansion and densification of district heating networks will increasingly lead to a corresponding reduction in gas consumption as well as to a resulting necessary re-dimensioning of the gas network.

Given that, there will most likely not be enough green gas to an extent to fully replace current fossil gas for space heating purposes, the question of which areas to prioritise for green gas use will be a rather important one to address. Thus, cities like Winterthur, are now heavily pushing towards decommissioning its current gas grid.

Also, other cities like Vienna are taking quite the stance on limiting the prospective use of green gas in space heating and reserving it for meeting peaks in the heating and electricity grids, and for industrial high temperature usages. In these cases, the gas grid will be partially decommissioned.

In case of usage of (bio- or synthetic-) methane for households, the gas grid and the customer appliances can stay in use. (But: The potential for biomethane is very limited - see above.)

In the case of switching to (green) hydrogen, gas grids and almost all customer appliances (heating systems, stoves, etc.) that are not “hydrogen ready” (and today almost none of them are) have to be converted or exchanged. And this at the same time! Which means that customers will have to switch their heating system at a specific point of time. Thus, switching to hydrogen heating does not avoid interventions in buildings and/or households and does not avoid political governance to orchestrate a synchronised switch of all customers in specific areas of the gas grid from fossil methane to (green) hydrogen.

4. Define Core Principles For a Future H/C System

Based on the specific approaches to certain energy carriers and sources described earlier, many cities have established basic principles that have subsequently been taken into account in the design of heating and cooling plans.

The H/C Outlook sets boundaries based on what is possible in terms of future potential and what are limitations. There are different approaches to set these boundaries and to work based on them:

I. Current situation approach

II. Source approach

III. Demand approach

In the following, an example is given for each approach. In most cases, the example shows a combination of approaches used, e.g. an approach that addresses both, sources as well as demand.

I. Current situation approach

Use the current situation as a starting point to give (general) direction to the transition

The City of Vienna has in its ambition towards phasing out gas till 2040 developed a “spatial principle” (see Figure 3).It pictures the basic premises of what the heating system will look like in the future: For current gas consumers with a demand for low-temperature heat (and for cooking), the basic principle conceived is the substitution of gas. Depending on the (future) heat demand density there are different solutions: if located near the current central district heating network, connection to it is preferred. If the distance to the central district heating network is too far, the establishment and connection to a local heating network instead (islands of district heating, or “Nahwärmenetz”) is pursued. If and where possible, all local excess and renewable heat resources should be exploited and integrated into these networks. In areas not in vicinity neither to a central nor to local heat networks, the use of decentralised heat pumps or biomass is suggested. For current gas consumers with demand for high-temperature heat, the corresponding basic principle is to switch to electricity as far as possible. If and where electrification is not possible in the future, the use of renewable gases should be prioritised.

As such, the city estimates that 50% of the buildings, currently heated with gas, will be sourced via a district heating network. In less dense areas, heat pumps will act as main source for heating. Green gas will, in turn, play a rather minor role. It is to be available for co-generation plants and other energy-efficient applications but not for heating buildings or supplying hot water (or cooking in households).

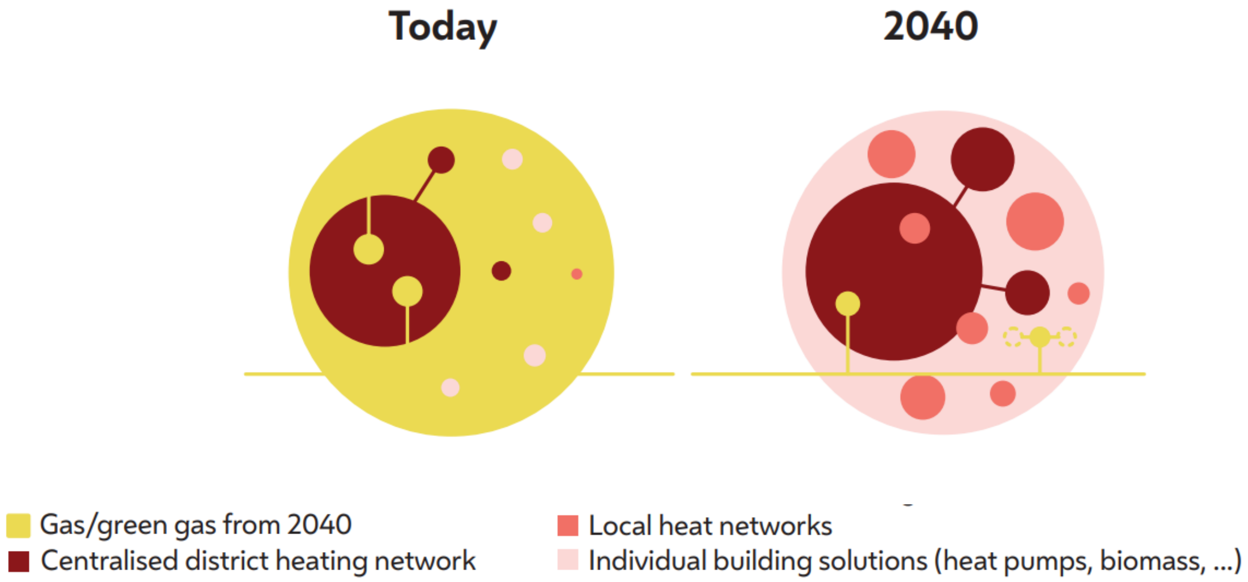

Figure 3: Vienna's spatial principle based on its heating outlook for 2040[10]

The following Figure 4 shows Munich's decision tree, which was developed to choose suitable measures for buildings.

[10] City of Vienna 2022: Phasing Out Gas. Heating and Cooling Vienna 2040. https://www.wien.gv.at/stadtentwicklung/energie/pdf/phasing-out-gas.pdf

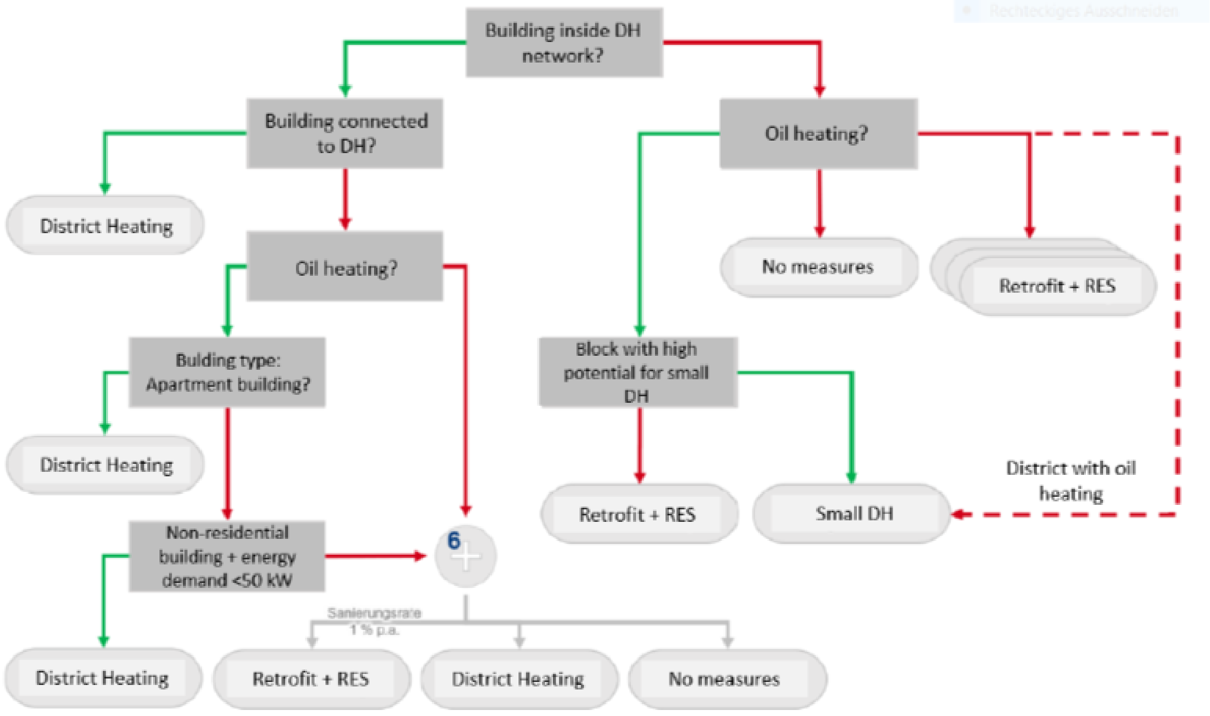

Figure 4: Decision tree for the development of measures[11]

II. Source approach

Use the potential supply and the preferred use of (heat) sources as a starting point to give (general) direction to the transition

The Canton of Zurich, in which the City of Winterthur is located, lists the use of the following heat sources as priority:

- Waste heat,
- spatially set, environmental heat (groundwater, geothermal heat),
- other environmental heat (sun, air) and wood.

The following Figure 5 shows the decision process for finding an area for district heating and its level of flow temperature:

[11] Munich´s Heating and Cooling Plan. Part of D3.3. https://decarbcitypipes2050.eu/wp-content/uploads/2022/09/D3.3.-HC-plan-Bilbao.pdf

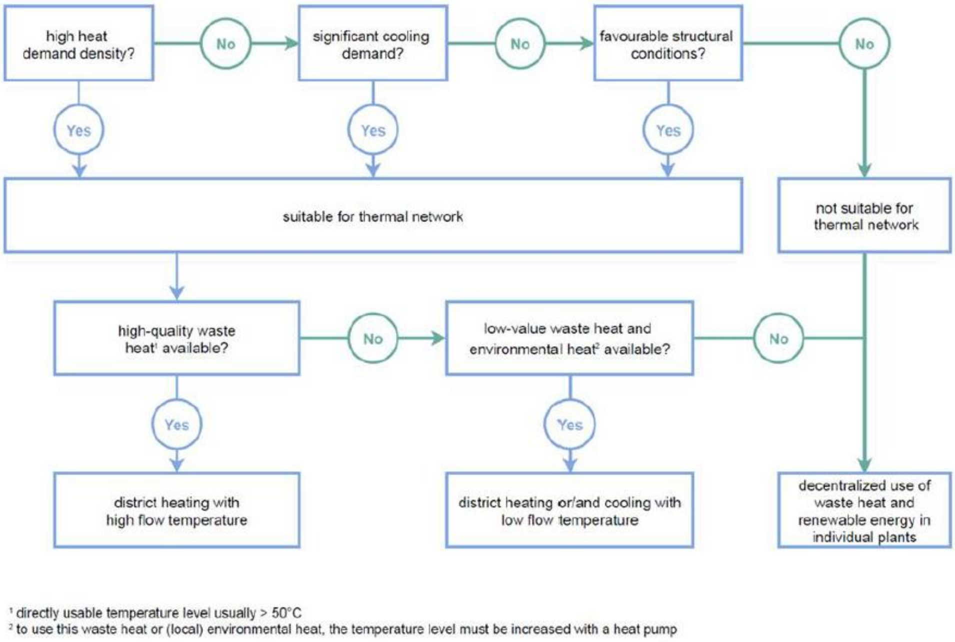

Figure 5: Decision scheme for the Canton of Zurich

III Demand approach

Use the expected heat (density) demand as a starting point to give (general) direction to the transition

Rotterdam decided to use high-quality sources like sustainable gases as much as possible for high-quality demand. They will, however, be very economical with scarce sources. Biomass will thus be used for food and animal feed, construction materials and chemicals rather than as fuel. Figure 6 shows the available alternative heat sources to natural gas that the city is considering.

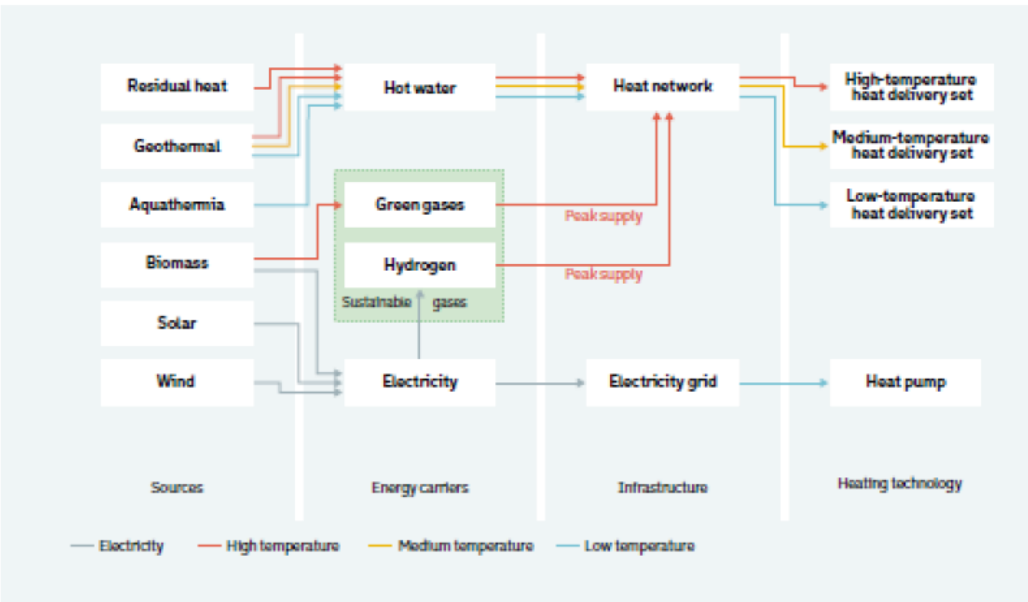

Figure 6: Decision tree for choosing sources in the City of Rotterdam

5. Get the Right Data

Data, no matter whether its geospatial or non-spatial data, is the cornerstone of an H/C outlook and, in general, energy planning. The most important key element is appropriate and sufficient information about buildings (and properties), including the energy supply system. However, there is often still a need to fill data and knowledge gaps in cities. More information on data issues have been compiled in the report on *Data availability and Sovereignty (D2.4*[12]*)*

However, good enough data should be good enough to move forward with a heating and cooling plan. Otherwise, one might face the risk of keeping on digging for data while making no progress with implementation.

The three-step approach WHAT – WHERE – HOW takes into account that cities will most likely start working with more general information and proceed to include more and more detailed information:

- The outlook (WHAT) gives general insights into what the potential heat supply and demand are and how those relate to energy infrastructures.
- H/C plans (WHERE) already dig deeper into what is possible where, based on more detailed (spatial) information (techno-economical spatial analysis[13]).
- Finally, in the last steps, cities elaborate detailed roadmaps and plans ready for decision-making.

Identifying Data / Knowledge Gaps

Make a comparison between the data already available and data still required. Some gaps may be filled by workarounds, e.g. missing values for gross floor area on building level can be derived from digital surface models (DSM) and digital terrain models (DTM). Points of interest (POI) data could also be included if the exact type of use of a building is not available.

It is advisable – especially further down the process while making H/C plans – to collect detailed data on gas infrastructure and specific information on cooking and process gas consumption. For district heating, it is not sufficient to only know the location of the grid infrastructure, the type of pipes or the hydraulic-dynamic system. Additional information about the remaining capacity is essential for planning purposes (e.g. information about sub-stations/transformers). For electricity data, it is advisable to collect information on remaining capacities, especially for charging stations and heat pump applications.

Assessments about renewable energy potentials should take into account any limitations on implementation (technical potentials). However, it is impossible to calculate potentials bearing in mind all economic, legal, static or other limitations for

[12] Data availability and Sovereignty (D2.4) 2022: https://decarbcitypipes2050.eu/wp-content/uploads/2023/06/DCP-2050_D2_4_220701.pdf
[13] Techno-economical possibilities and system correlation (D2.3) 2021: https://decarbcitypipes2050.eu/wp-content/uploads/2021/07/DCP-2050-Techno-economical-possibilities-and-system-correlations.pdf

each building and property. Nevertheless, it is recommended to calculate all potentials on the “smallest” possible spatial level. For instance, the shallow geothermal potential could be calculated down to the property level (from 30 to 200 metres) regarding water protections zones and non-built up areas. Solar potential of roofs could be calculated only for useable areas of each roof, while including reducing factors well known from practice. All calculated potentials should be easily accessible for everyone to trigger the use or the interest on renewable energy potentials.

It is recommended to compare the energy demand with the energy supply in the future. Special attention should be paid to both, the spatial and temporal components of the comparison. Annual balances for an entire city often show a distorted picture of reality.

Clear Identification of Data is Crucial

Energy data models need accurate data, specifically on building level. It is often challenging to identify the right ID (identifier) to link different data sources. Hence, the definition and the identification of data is crucial and the earlier in the process these definitions are made and widely agreed upon, the easier the process of making more detailed plans will be. For instance, the element “building” in the building register could denote a different physical object in another data source. Thus, there needs to be a commitment to universal identification of data for different spatial levels or statistical units, e.g. energy demand of non-residential buildings as well as adequate information about residual/waste heat (especially on low-temperature levels) still pose challenges to all project participating cities.

Set-Up of a (Geo) Data Management

It is advisable to set up a (geo)data management within the unit responsible for energy issues and to define adequate time and personnel resources, especially for data acquirement and the maintenance of data or data models. Set up of a data exchange between different departments or, in case necessary, between the city and the grid operator / energy providers. To this end, it is oftentimes also necessary to base the exchange on laws or legal contracts. Some data could also be provided as open data.

Integrate Data Gathering into Recurring, Official Procedures

The quality of models is only as good as the underlying input data. To improve data quality, the following is suggested: comprehensive assessment of the building stock through on-site inspections. However, due to time and resource constraints, this is oftentimes not feasible. Thus, a moderate level of data quality needs to be achieved that meets the requirements of the respective project. It needs to be decided which data quality level (and which deviations are ok respectively) is necessary for which task. In the long-run, it is advisable to integrate data collection into existing procedures, e.g. in the case of building permits or other official notification.

Update Data on a Regular Basis

An essential question also arises when it comes to updating the data on a regular basis. Depending on the type of data this can range from immediate updates in a database to annual updates (or even longer periods). As a minimum, key dates or the periods should be agreed and communicated.

6. Use Typologies

Halmstad University and the City of Vienna developed (based on a newly developed methodological framework[14]) a total of six specific urban-typologies-based design approaches. These were developed partly on the basis of the specific local conditions in the project cities and partly on the basis of general principles of heat planning. They were created to identify possible solutions and recommendations for decarbonizing the heating and cooling sector in different parts of a city. The design-approaches differ between short-term solutions (until 2030) and long-term solutions (2050).

In Case of High Heat Demand Density: Central Supply Solutions

Short-term approach: Consider to expand current district heating into new areas and, where applicable, plan for conversion to low-temperature operation. Increase connection rates to these systems and, if there is no district heating at current, begin preparations for the installation of new systems.

Assess the potentials for energy from wastes and the integration of renewable and waste heat sources to replace current central fossil supply (deep and shallow geothermal energy, large-scale heat pumps, all kinds of waste heat, sustainable biomass, solar thermal, water bodies in vicinity etc.) and decide, where applicable, which areas should be disconnected from gas and when.

Long-term approach: Expand current district heating into new areas and, if no district heating exists today, plan and build new systems. Focus on maintained high heat density in the built environment in these areas and establish long-term urban planning strategies for both heat and cold supplies.

Seek to spatially coordinate the expansion and new construction of district heating systems with the orderly phase-out of fossil-based supplies, arrange for energy from wastes capacities and the systematic integration of renewable and waste heat sources in the central supply. Focus on central energy storage solutions.

In Case of Average Heat Demand Density: Central And Individual Supply Solutions

Short-term approach: In districts with sufficiently high heat demand densities, consider to expand current or prepare for new district heating systems, increase connection

[14] For more details see

- H/C Outlook 2050 of Cities with Cross-City Synthesis (D2.6) 2022: https://decarbcitypipes2050.eu/wp-content/uploads/2023/06/DCP-2050_D2_6_Final-version-for-submission-Edited-version_221213.pdf
- Decarbonisation design-approaches based on urban typologies (D2.5) 2022: https://decarbcitypipes2050.eu/wp-content/uploads/2023/06/DCP-2050_D2_5_220916.pdf

rates, and plan for conversion to low-temperature systems where applicable (decentralised networks or networks connected to a centralised system). Consider energy zoning and, at lower densities, prioritise investments in individual energy efficiency measures.

Assess the potentials for energy from wastes and the integration of renewable and waste heat sources to replace current central and individual fossil supplies. Special focus on individual electrification of heat demands especially in less dense areas. Decisions on which areas should be disconnected from gas and when.

Long-term approach: Introduce new, or expand current, district heating systems in districts with sufficiently high heat demand densities, establish as high connection rates as possible, and seek long-term densification of these areas. Apply energy zoning (perhaps under mandatory connection principles), and arrange support for building refurbishments, energy savings, and individual electrification of heat demands in less dense areas.

Convert to low-temperature district heating systems where applicable in order to facilitate higher direct integration of renewable and waste heat sources to replace current central supply. Electrify individual heat demands to replace current individual fossil supply.

In Case of Low Heat Demand Density: Individual Supply Solutions

Short-term approach: Investigate possibilities and suitable support for energy savings in the current building stock, initiate refurbishment activities, and replace old fossil-based heat supply systems with focus on individual building or building block installations.

Seek electrification of heat demands by use of individual heat pumps, perhaps by utilisation of shallow geothermal energy resources, ground water assets, roof-mounted solar photovoltaic panels, air, and similar.

Long-term approach: Perform energy savings in the current building stock by the orderly arrangement and enforcement of refurbishments activities, focus on programs for high-efficiency future buildings, and, in districts in close vicinity to low-temperature district heating systems, plan for possible future connections.

Maintain focus on the electrification of building heat demands by use of individual heat pumps with support also for other individual solutions, such as geothermal probes as building-level storage systems combined with solar thermal panels, utilisation of local green gases based on residues from regional forestry and agriculture (perhaps by using existing infrastructures), as well as other locally available energy assets. Focus on individual energy storage solutions.


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DECARB CITY PIPES 2050

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