DECARB CITY PIPES 2050

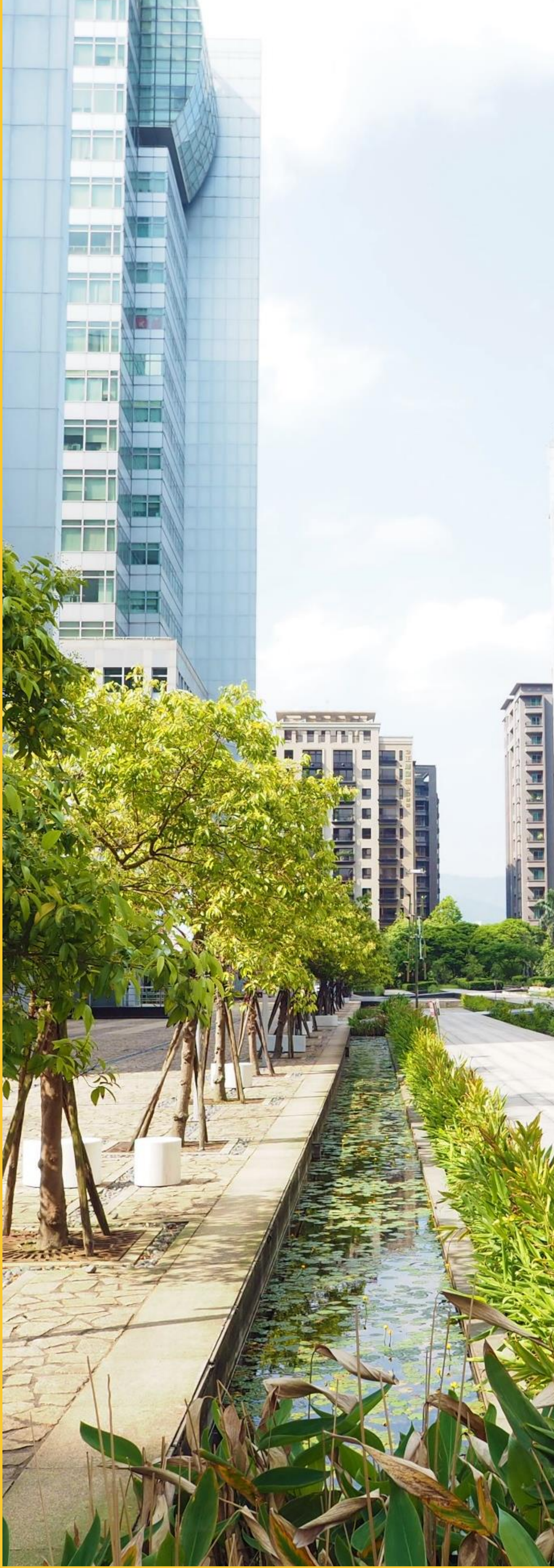
Training of cities on H/C tools & techniques

Deliverable 3.1

AUTHORS
Prepared by Amélie Ancelle, Energy Cities
Reviewed by Astrid Madsen, Consultant

Published: April 2022

PROJECT INFORMATION
Project name: Decarb City Pipes 2050
Grant agreement number: 893509
Project duration: 2020-2023



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

Table of Content

List of Figures

List of Tables

Executive Summary

Tools & techniques for decarbonised H/C.

Common challenges are faced by cities who are committed to decarbonise their heating and cooling systems:

- How to deal with the temptation of the green hydrogen hype?
- How to strategically use waste heat which has still the status of untapped potential in many cities?
- How to ensure that the most cost-effective solutions are chosen, in accordance with the question of capacity (financial and human) and of technique?

The different tools and techniques presented to cities during knowledge transfer sessions tackled three different themes: green gases, waste heat, and cost and energy modelling.

Presentations and exchanges between cities and experts underlined three main points.

First, green hydrogen is not yet a mature enough technology to be the challenger for heat systems decarbonisation. It is not cost-efficient compared to existing technologies and will require massive investment and works, whose costs may be reported on consumers. To avoid any potential lock-in effect for the decarbonisation of heating systems, the primary target use for geen hydrogen should be the decarbonisation of hard-to-abate sectors, like heavy industries.

Second, negotiating with companies is key to reaching an agreement on the use of waste heat. This means reflecting on the best way for a city to contract with the companies, reflecting on the payback time, the possibility of an insurance scheme and also to foresee a backup plan if the waste heat source moves away.

Last but not least, when looking for the most cost-effective solutions, the main parameter to have in mind is that cost is heat demand density dependent. Access to a wide variety of data is thus key, and developing methodologies or inventive ways of coping with the absnece of data is also crucial to ensure that the modelling is as close as possible to reality.

Those exchanges brought a first step to the constitution of a community dedicated to decarbonise its heating and cooling systems. Proven tools and techniques already exist and are described in the different sections of this deliverable.

Introduction

Context and overall objectives of the project

Transition Roadmaps to energy efficient, zero-carbon urban heating and cooling. Seven cities are getting real about showing fossil fuels the door. Climate urgency calls on all political levels to act more stringent and faster. In this EU-project seven cities - Bilbao, Bratislava, Dublin, Munich, Rotterdam, Vienna and Winterthur - team up to work out actionable roadmaps to decarbonize heating and cooling for buildings in 2050, taking up the challenge of phasing out natural gas in heating.

Responsible for roughly half of the EU's final energy consumption, transitioning heating and cooling to energy efficient, renewable solutions will be critical to bring EU countries in line with their pledged climate and energy targets. Given the long-life cycles of the grid infrastructures involved, there is an urgency to start the planning of this transition today. But how? What first? Which systems? How to govern this process? Increasing complexity of the energy system together with technological uncertainties require a high level of knowledge and skills to act wisely. Cities are not yet fully equipped for this. They lack capacity and skills as well as legal empowerment to act.

Decarb City Pipes 2050 showcases how local authorities can build capacity to succeed in this challenge. Seven cities - from frontrunners to beginners - join forces to learn from each other and elaborate innovative responses together. They explore pathways suitable for their local challenges and build up skills in the use of data, planning tools and instruments, techno-economic as well as process and transition management knowhow. In a participatory process with stakeholders, they develop tangible transition roadmaps, building up trust and commitment for its implementation along the way. In deep peer-to-peer exchanges, cities and utilities share knowledge to benefit from other perspectives, stages of advancement and planning traditions.

Together, they will advocate for the needed changes to framework conditions. Guided by two scientific partners and a distinguished advisory board, the project aims to empower more than 220 public officers and improve more than 50 policies. Ultimately, it strives to motivate and support more than 80 cities to start the same roadmap process.

Objective and purpose of the deliverable

This report D.3.1. Training of cities on H/C tools & techniques is based on the various knowledge transfer activities organised under task 3.1 Knowledge transfer on H/C planning, as one of the steps cities need to take in their transition towards fossil free heating. The objective of this deliverable is to give an overview of the different tools and techniques regarding heating and cooling shared with cities and assess their potential usefulness for municipalities and come to a spatial planning for heating and cooling solutions. Social aspects of the transitions are not accounted for in this deliverable, but making the transition fair, just, and inclusive remains nonetheless key and should not be neglected.

It starts with the description of the general process which was followed to organise those sessions, before deep diving into the tools and techniques which were presented. Finally, an assessment of the usefulness of these tools and techniques for cities is provided. This assessment is based on a satisfaction survey, the various questions and interactions observed during the sessions, as well as feedback from developers and first users of those tools.

Providing a first evaluation of those mapping and planning tools and techniques should serve a multi-layered purpose. First, have a clear understanding of what the needs of cities are, in terms of developing further their heating and cooling plans from a technical point of view. Second, the presentation of those tools and techniques should also benefit cities outside of the consortium, given the public character of this deliverable. Finally, it will also orientate future demands and advocacy work done under this consortium, to make sure that they are aligned with the reality of the ground.

Choice of tools and techniques

Organising the choice of topics

To make sure that the proposed topics were fitting as close as possible the interest of cities in the consortium, Energy Cities consulted the Decarb City Pipes 2050 partners. We listed different topics, technologies, and the different concerned phases, echoing questions initially formulated by partners. They were then asked to rank between 0 and 3 each of those different topics, 0 representing the lowest priority and 3 the highest. Partners were then asked if they wanted a specific capacity building activities tackling those topics, and if some of them were a very short-term priority (*e.g.*, in the first half of the project). Members could also include additional topics if they wanted to, but none did.

As a result, the most voted topics regarding heating and cooling tools and techniques covered various topics and allowed the exploration of a wide scope of tools and techniques. The topics of green gases, waste heat, and cost modelling appeared as key topics for cities willing to decarbonise their heating systems. Presenters were mostly external from the consortium, except with the presentations from the partners of Halmstad University which co-led this task. The table below gives an overview of the content of the different sessions.

<table>
<tr><th>#</th><th>Presentations</th><th>Presenter</th></tr>
<tr><td>1</td><td>Hydrogen, alternative gases and decarbonising cities</td><td>Lisa Fischer, E3G</td></tr>
<tr><td rowspan="3">2</td><td>The technical aspects of harvesting waste heat from data centres and seasonal storage</td><td rowspan="2">Matthias Kolb, Anex Ingenieure AG</td></tr>
<tr><td>Implementing district heating in interaction with local actors (examples of Zürich, and St Gallen)</td></tr>
<tr><td>The potential to recover waste energy</td><td>Kristina Lygnerud, Halmstad University and Swedish Environment Research Institute</td></tr>
<tr><td rowspan="3">3</td><td>General overview of the principles of cost modelling</td><td>Dr. Urban Persson, Halmstad University</td></tr>
<tr><td>The case of the Metropolitan City of Milano</td><td>Dr. Alice Denarié, Politecnico Milano</td></tr>
<tr><td>Overview of PlanEnergie’s study on modelling tools</td><td>Per Alex Sørensen, PlanEnergi</td></tr>
</table>

TABLE 1: DETAILED PROGRAMME

Challenges faced by cities

The topic of **green gases** has been the first covered. Each city in the consortium has a more or less big share of (natural) gas in its heating mix. The question of green gases, especially related to hydrogen, is thus of prior interest. Every country has developed or is in the process of developing a hydrogen strategy. However, more and more voices are raising to show that the use of hydrogen for heating purpose would be far from being cost (or energy) efficient. As shown in Figure 1 below, taken from Decarb City Pipes 2050 deliverable D.2.3. “Techno-economical possibilities and system correlations”, the initial electricity input for the use of hydrogen in heating systems is the least efficient, compared to other available technologies. One limit of this figure to bear in mind is that district heating is here only considered under the prism of electricity. However, district heating uses most of the time other heat sources than electricity (or sometimes in combination with electric upgrading). The efficiency of these solutions would thus be different (higher) than what is presented on the figure.

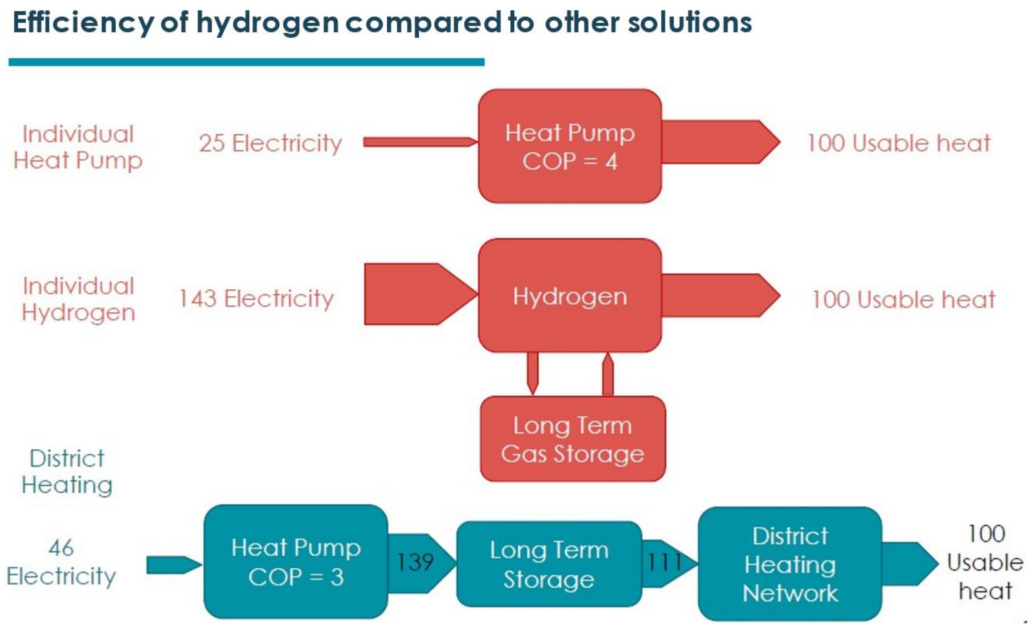


FIGURE 1: EFFICIENCY OF HYDROGEN FOR HEATING COMPARED TO OTHER SOLUTIONS

Beyond the pressure of hydrogen, the political pressure in some cities of the consortium to replace old oil boiler by gas ones (fossil or green) was also a major challenge. With more information on the different techniques related to green gases, the idea was to provide technical arguments to the discussion. The aim of the knowledge transfer was to answer the following questions:

- For which kind of consumers/buildings might green gas be useful (historical buildings, high-temperature heat demand for production) for H&C?
- How does it fit in the city's strategy?
- Is it fully renewable and where would it come from?
- What is the potential of green gas production locally?

The second topic to be explored touched upon **waste heat**. Several cities in the consortium are interested in the topic, especially Dublin, which will benefit from the excess heat from data centres and industries to start a new district heating network. The city of Rotterdam is also looking at possibilities to use waste heat from the industry. This topic is seen as strategic by all cities, since waste heat can come from very different sources in a city (see Figure 2 from the ReUseHeat project).

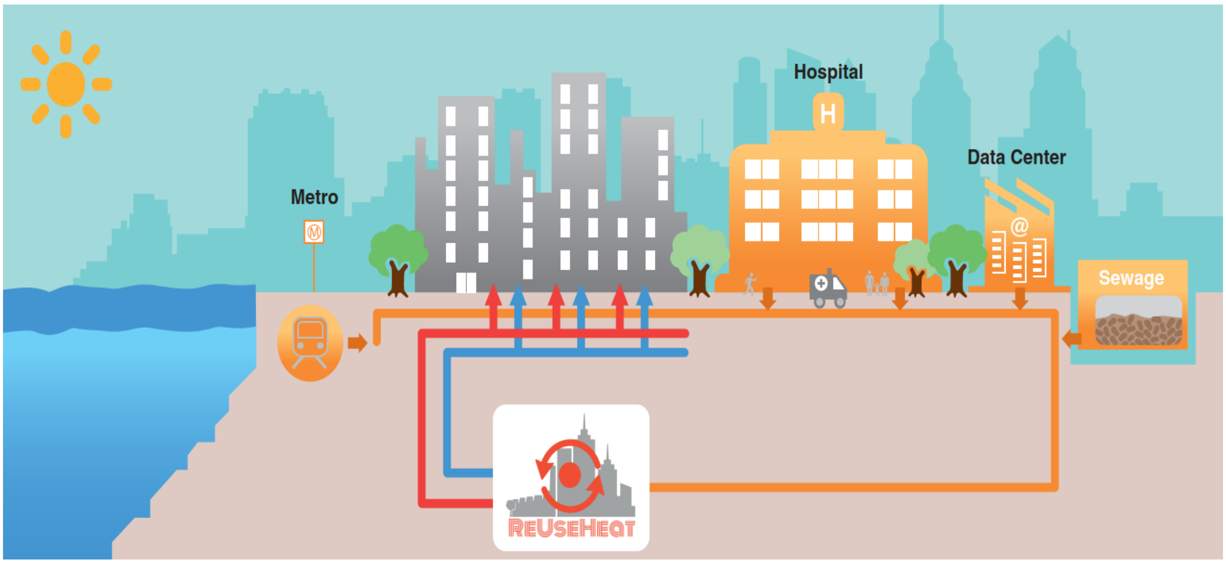


FIGURE 2: POTENTIAL SOURCES OF WASTE HEAT

However, the incorporation of waste heat in a heating system implies the involvement of very different stakeholders, public and private, with different goals and timelines. The idea of exploring tools and techniques to recover waste heat and include it in a district heating network was to give cities the right tools to benefit from this untapped enough potential which it represents. The aim of the knowledge transfer was to answer the following questions:

- What is the potential of waste heat?
- How to recover it?
- How to ensure that waste heat providers supply DHC networks?
- How to map and quantify unconventional heat sources?

Finally, tools and techniques for **cost and energy modelling** also ranked as very interesting for cities. Every city in the consortium agreed on the importance of data to develop sound heating and cooling plans. This is also a general acknowledgement beyond this project. However, data are scattered between various stakeholders and even sometimes not available at all. There are already existing tools for mapping potential sources. They can focus on the national, regional, district or even building levels and offer different characteristics. A brief summary of existing tools used by local authorities at district level can be found in Table 2. Tools for the building level are most of the time developed in-house by a specific department of a municipality or by the local energy agency.

Tool	Free?	In-built data	Language	Main user profile
City Energy Analyst	Yes	Yes	English	Planning departments Energy agencies & consultancies
Thermos	Yes	Yes	English	Planning departments Energy agencies and consultancies District heating companies
PlanHeat	Yes	Yes	English	Planning departments Energy agencies and consultancies District heating companies

Hotmaps	Yes	Yes	English	Local authorities Planning departments Energy agencies and consultancies Universities

TABLE 2: OVERVIEW OF EXISTING TOOLS FOR H/C

Facing all this variety of options, the question of capacity of use (financial and human) and of technique remains crucial. Since many tools already exist, the idea of the knowledge transfer session on cost and energy modelling was really to focus on the techniques to make cost-efficient decisions. Through this, cities are still left the choice of tools they want to use, while be assured that they are exploring the most techno-economic viable options in their modelling. The aim was thus to answer the following questions:

- How to gather good building-level data (confidentiality, commercial value, availability and production of data)?
- How to get good data on RES potential (confidentiality, commercial value, availability and production of data)?
- How to assess cost-efficient technologies per district?

The following sections are focusing on the content of each knowledge transfer activities and underline the main takeaways regarding each problematic.

Green gas in the city

Hydrogen* is often presented as a quick fix to get rid of fossil fuels for heating and cooling in cities. But it is widely debated by experts and has some uncertainties and risks of lock-in effects. Lisa Fischer, Programme Leader at E3G, questions this statement and discussed with cities the role that hydrogen can play in the decarbonisation of cities.

Is hydrogen efficient?

Green hydrogen requires five times more electricity to heat a home than a heat pump. In other words, hydrogen-based low-temperature heating systems consume 500 to 600% more renewable energy than heat pumps. Indeed, the transport, storage, multiple stages transformation and combustion of hydrogen lead to multiple losses.

Richard Lowes from the University of Exeter, concludes: “In every bit of analysis I’ve seen, whether it’s hydrogen or electrification, you have to do efficiency to make things cost-effective.” Figure 3 below illustrates the difference of efficiency between green hydrogen and heat pumps[1].

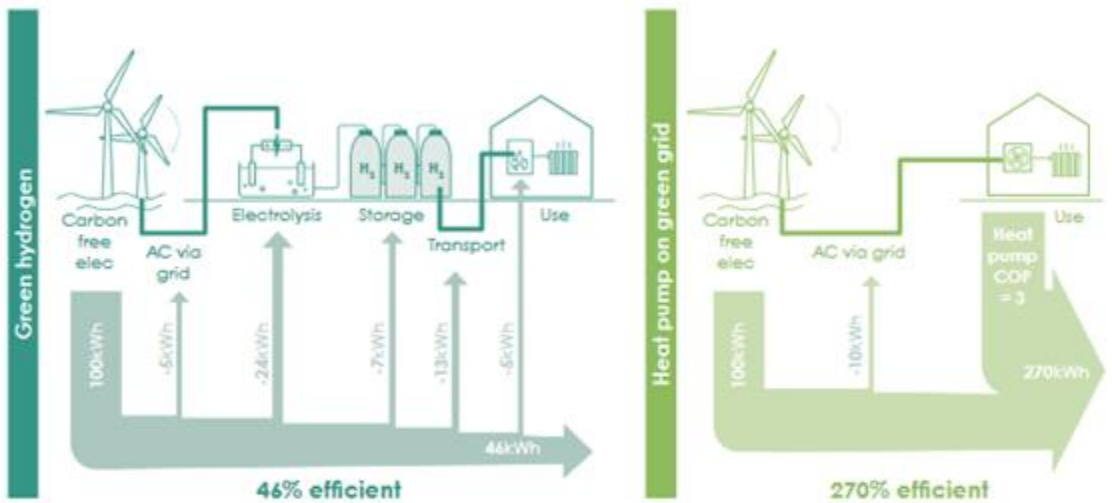


FIGURE 3: THE DIFFERENCE OF EFFICIENCY BETWEEN GREEN HYDROGEN AND A HEAT PUMP SUPPLIED BY A GREEN GRID

Furthermore, the argument of whether hydrogen is actually “green” needs to be questioned. Biomethane still emits CO_2 at combustion stage and potential methane through production and transportation. It is thus only net-zero if the production method leads to additional capturing of CO_2 or avoidance of waste. Hydrogen, on the other hand, does not emit CO_2 at the point of combustion, but there may still be (significant) lifecycle emissions including from:

- Fossil gas production and transportation through methane leakage (for so called blue or turquoise hydrogen)
- The limitations of the carbon capture method (the maximum achieved is so far 95%)
- The electricity used to produce electrolysis hydrogen.

[1] *Source: LETI hydrogen Report, Data source: Prof David Cebon*

Is hydrogen cost-competitive?

The cost competitiveness is relative and data must be compared within the different low carbon alternatives to heat cities: heat pumps, district heating, and hydrogen boilers. The cost analysis differs greatly according to the criteria used: considering the evolution of hydrogen and electricity prices, estimated temperatures in a few decades, infrastructure, etc.

That being said, scientific studies[2] conclude that, to deliver a comparable amount of heat for residential heating, hydrogen is not competitive in heating, as air-source heat pumps are at least 50% lower cost than the hydrogen-only technologies. The ICCT even concludes that "if natural gas costs were 50% lower or renewable electricity prices were 50% higher in 2050 compared to our central assumptions, heat pumps would still be more cost-effective than hydrogen boilers or fuel cells" which is an argument not to be dismissed, considering the social aspect of the energy transition.

Indeed, as explained above, hydrogen-based heating technologies need much more energy than heat pumps and a major part of green hydrogen's price consists of electricity's price. Which means that when the price of renewable electricity drops, it will be a saving for both hydrogen and electricity which will always be cheaper.

Moreover, some experts predict that if hydrogen is used massively for heating it will double hydrogen costs. A shortage of hydrogen would induce competition between different sectors (industry, chemicals, storage) which would push up the prices.

Nevertheless, unrenovated buildings are the notable exception where hydrogen may be more competitive. This means that, in theory, hydrogen could be used as a decarbonisation solution before large-scale (deep) renovation is carried out. However, this would create a potential lock-in threat, meaning that hydrogen for residential heating is not a viable, sustainable, long-term solution.The proposed Renovation Wave will reduce energy consumption for heat and the proposed Minimum Energy Performance Requirements under the Energy Performance of Buildings Directive (EPBD) would tackle these least-efficient buildings first and erase that potential market. To avoid this lock-in effect, the Renovation Wave needs to happen fast and be ambitious.

Finally, according to Lisa Fischer, the strategy of using "blue hydrogen" as a transitionary energy requires significant investments (in CCS) "that may not be justified if only used for a limited amount of time. Given the entanglement with fossil companies, this also bears a higher risk of lock-in and non-delivery which would need to be governed carefully."

What infrastructure for the use of hydrogen in cities?

Hydrogen has different properties than natural gas. Using 100% hydrogen for heating houses involves some changes in the network to bring gas into the houses and in the house's appliance itself. There are a number of different materials used for domestic natural gas pipework[3]. Consequently, in some houses, the changeover to hydrogen can be quick with only the change

[2] Source : https://theicct.org/wp-content/uploads/2021/06/Hydrogen-heating-eu-FS-feb2021.pdf

[3] Source: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/760508/hydrogen-logistics.pdf

of boiler and meter, but in others, it also requires the whole appliance to be replaced[4]. To facilitate this conversion work, which could take several days per house, gas companies are proposing to install already mixed boilers ready for future hydrogen use.

Research has shown that many uncertainties remain to be resolved and that beyond the acceptability of hydrogen by owners, "the inaccessibility of domestic gas pipework could be a significant barrier to conversion if pipework needs to be either fully inspected or replaced as natural gas pipes are sometimes covered by concrete or ducted through inaccessible voids".

Another limitation is the question of who bears the responsibility and the cost of these transformations. Compared to electrification or natural gas, investments in hydrogen will be riskier and will generate fewer capital returns given the unproven technology, uncertainties on hydrogen cost and up-scaling needed. As a result, more public and taxpayer investments should be made to finance construction work.

Is the use of hydrogen rather easy or disruptive for citizens?

This is an important question, very much linked to the infrastructure debate, raised by gas companies. According to them, hydrogen is a "like-for-like" solution: replacing natural gas with hydrogen is a painless and effortless solution for citizens. This non-disruptive argument is very attractive to policymakers but it is a bit vague. The change of gas could lead to a change in the bill as well, induced by the replacement of the inhabitant's home's and street's infrastructure (boiler, in-house pipelines, cooking stoves on the one hand, pipelines and compressors on the other hand). A study by ACER (the European Agency for the Cooperation of Energy Regulators) underlines that, currently, "it is highly unknown when and where these conditions [for the repurposing of NG pipelines in view of a new hydrogen market] would be met across Europe, and whether they will be met at all"[5].

However, it is important to bear in mind that transofrmations to switch to heat pumps or district heating will also require changes inside and outside buildings. Hence the need to carefully plan ahead to adapt the urban landscape through long-term, sustainable strategies.

When will hydrogen technology be ready to heat cities?

Analysing the UK projects and market, Centrica, the biggest gas supplier, admits that it will take more than ten years to produce green hydrogen for heating… while district heat and heat pump technologies are already available! Waiting for the hydrogen era to arrive for cities could create a terrible lock-in effect for the decarbonisation of heating.

Regarding the timeline, Jan Rosenow, from the Regulatory Assistance Project, points out: "Yes, do some research on hydrogen and do pilot projects, but it is a big bet to say hydrogen will solve

[4] Ibid.

[5] Source: https://extranet.acer.europa.eu//Official_documents/Acts_of_the_Agency/Publication/Transporting%20Pure%20Hydrogen%20by%20Repurposing%20Existing%20Gas%20Infrastructure_Overview%20of%20studies.pdf

our problems in 2040 and then not do anything in the meantime. I think that would be irresponsible."

To conclude, as Lisa Fischer puts it: "there is only a few end use sectors where it makes sense to deploy hydrogen and where demand is likely to emerge, notably where currently no alternatives are available"

Green hydrogen is not yet a mature enough technology to be the challenger for heat systems decarbonisation. It is not cost-efficient compared to existing technologies and will require massive investment and works, whose costs may be reported on consumers. To avoid any potential lock-in effect for the decarbonisation of heating systems, the primary target use for geen hydrogen should be the decarbonisation of hard-to-abate sectors, like heavy industries.

The original article was published on the website of Decarb City Pipes 2050 on 31 Mach 2021. Presentations are gathered in the "Library" section of the website.

Tapping the waste heat potential

General overview

Several cities of the consortium are interested in developing the use of waste heat for their district heating systems. However, they are facing several challenges: what is the potential of such a source? How can it be recovered? How to ensure that waste heat providers supply DHC networks? How to map and quantify unconventional heat sources? What are the solutions to make contracts between public authorities and the private sector?

In general, waste heat is excess heat that is generated during industrial processes or the normal functioning of infrastructure. The current amount of **industrial heat** recovery in the EU can be estimated at 3 exajoules per year, which is about 1% of the full technical potential[6]. It is usually at higher temperatures, since industrial processes often require heat temperatures between 50°C and 1000°C. The potential of **urban waste heat recovery** has been identified at 1.2 exajoules (equivalent to about 30 million tons of oil per year) for the EU, which corresponds to approximately 10% of its total heat demand[7]. Urban waste heat can be generated from the activities undertaken by the cities' inhabitants, such as taking the metro (radiated bodily heat), using the bathroom (heat arising from processing of sewage) or using a computer (heat from an activated data centre). Urban waste heat is usually at a lower temperature (below 50°C), with lower capacity per source. There is thus a large potential for waste heat recovery and yet, only a small percentage is recovered.

Technical aspects

To better understand the technical capacities of the use of waste heat, an external expert shared a couple of successful implementations of waste heat recuperation schemes. There is first the case of a family house energy cooperative in the Friesenberg area of Zürich – Familienheim-Genossenschaft Zurich (FGZ). The cooperative unites 5,500 residents in 2,300 houses. Two big companies, Swisscom and the Crédit Suisse, are installed in the area and use data centres. After one and a half years of negotiations between the cooperative and the companies, an agreement was reached: the cooperative and the data centres will be connected, to form a closed loop, recover the waste heat, and inject it into the district heating (DH) system for free.

The data centres have been equipped with heat exchangers and a seasonal heat storage tank was installed. The extracted heat can either go straight to the housing units or be stored in the tank for later use, in the winter for instance. The evolution of the heating & cooling systems of the data centres and of the DH can be seen in Figure 4 and Figure 5 below.

---

[6] *Miro L, Brückner S, Cabeza LF. Mapping and discussing Industrial Waste Heat (IWH) potentials for different countries. Renew Sustain Energy Rev 51 (2015) 847-55*

[7] *Persson, U.; Averfalk, H. Accessible Urban Waste Heat. Available online: https://www.reuseheat.eu/wpcontent /uploads/2019/02/D1.4-Accessible-urban-waste-heat.pdf*

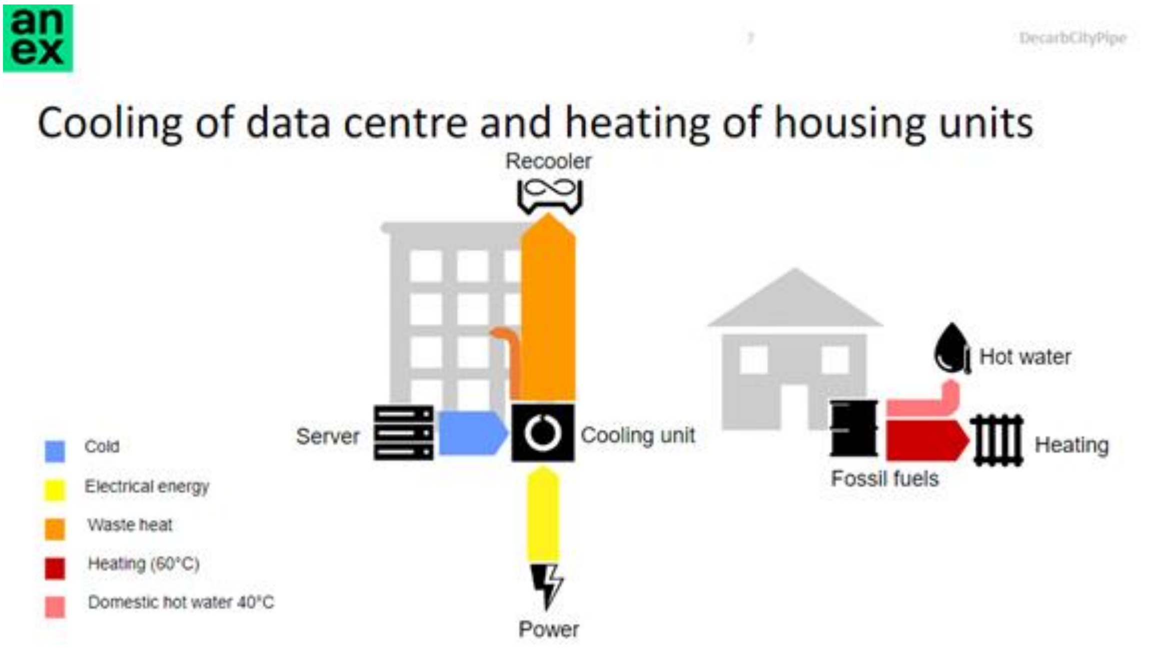


FIGURE 4: THE HEATING AND COOLING SYSTEMS BEFORE THE CONNECTION OF THE DATA CENTRES[8]

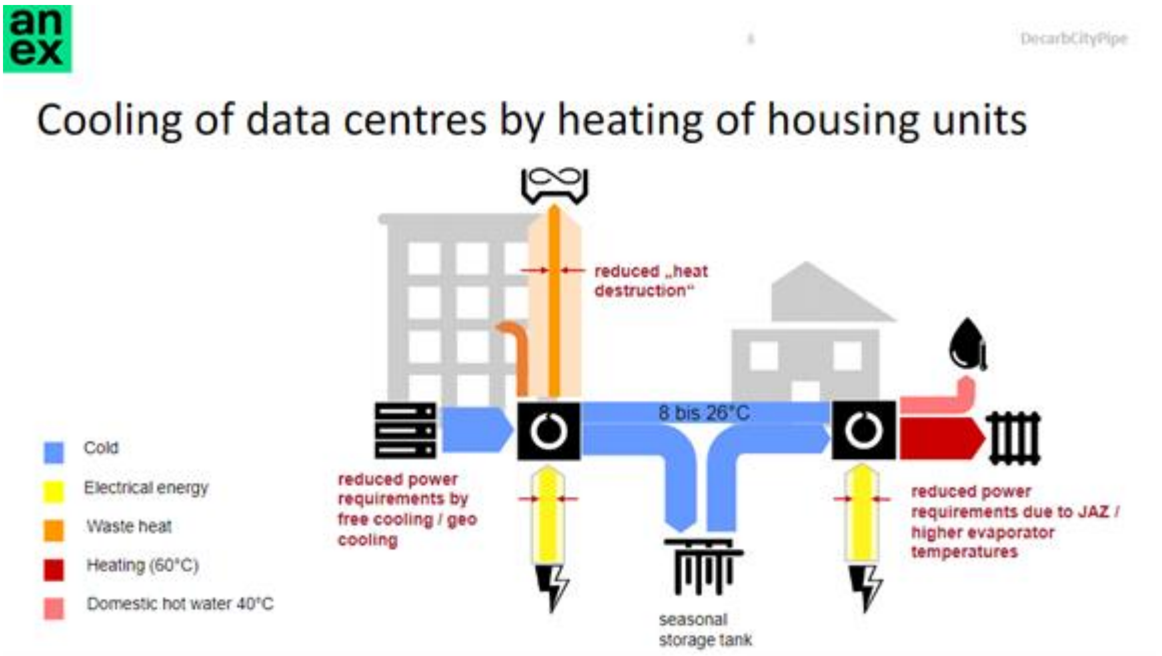


FIGURE 5: THE HEATING AND COOLING SYSTEMS AFTER THE CONNECTION OF THE DATA CENTRES

Thanks to this, CO2 emissions have observed a 35% yearly decrease in the cooperative. In addition, the water savings sum up to the equivalent of four times a 50-metre swimming pool.

Another example from the industrial area of Gaiswerwald, in St. Gallen (a sister city in the Decarb City Pipes project), saw a strong participation of local actors to have waste heat included in the DH system. The local energy association noticed that, from a technical perspective, this area was excellent due to the high, yet unused, waste heat density, with the 17 private companies in the surroundings. After negotiations and reflection from the municipalities and energy suppliers,

8 Source: Presentation by Matthias Kolb, Engineer at Anex Ingenieure AG, Zürich a company was founded to make a public-private partnership with the concerned industries who agreed to participate in a common heat distribution network, providing sustainable heating to the nearby area.

Those technical examples underlined the typical barriers encountered by cities when trying to harvest waste heat. However, the main barriers to waste heat recovery are typically not technical in nature. They are related to regulation and to stakeholders identifying the possibility of undertaking activities outside of their core business and with new partners:

- First, the price of waste heat is much discussed: often the owner of the waste heat and the district energy provider have different views on the value of a certain amount of heat. Putting all of one's eggs in one basket is also seen as a risk: what if the waste heat provider shuts down its activity[9] and what happens if customers eventually decide to leave the grid? One solution to mitigate barriers is to write precise contracts containing relevant clauses such as mitigation (what happens if either party fails to meet its obligations), regular updates of contracts (to remind why the waste heat recovery was undertaken in the first place) and clear boundary conditions (where does responsibility begin and end). The ReUseHeat project offers good examples of contractual forms, which have been shared with participants of the session.
- A large barrier that cannot be contracted away is that of regulation falling short of supporting waste heat recovery. The Directive on the limitation of emissions of certain pollutants into the air from medium combustion plants sets a frame in terms of limitations of CO_2 emissions from industrial processes. However, it does not cover "combustion plants in which the gaseous products of combustion are used for the direct [gas-fired] heating". In addition, the proposed revised Energy Efficiency Directive in Article 24 defines an efficient district heating by 2050 as one fully relying on renewable energy and waste heat. If the process is encouraged, a better framework to define green waste heat could be beneficial to better understand how and when it is comparable to a renewable energy source
- Directly linked to this lack of definition is the absence of legal framework for waste heat in Europe which accounts for risk. Yet, when there is risk, there is lower appetite for investment and so waste heat investments are not taking off but rather competing with incentivised investments in other forms of renewable energy. An alternative to mitigate the risk would be for insurance companies to invest in DH at early stages: that way they could be close to the investment and mitigate if industrial activity was closed.

Negotiating with companies is key to reaching an agreement on the use of waste heat. This means reflecting on the best way for a city to contract with the companies, reflecting on the payback time, the possibility of an insurance scheme and also to foresee a backup plan if the waste heat source moves away.

The original article was published on the website of Decarb City Pipes 2050 on 4 November 2021. Presentations are gathered in the Library section of the website.

[9] *Lygnerud K, Werner S. Risk assessment of industrial excess heat recovery in district heating systems. Risk assessment of industrial excess heat recovery in district heating Systems, Energy 151 (2018) 430-441*

Tools and techniques for cost and energy modelling

General overview

The question of costs is always in the first ones to arise, when discussing decarbonisation of heating systems, especially when the question of developing a district heating network is on the table. Because realising a new District Heating system needs high upfront investments, while heat pumps also need investments, this can be done building by building (and thus have a different risk profile). To look for the most cost-efficient solution is therefore a priority for cities. Deliverable D.2.2 “Draft recommendations for H/C outlook 2050” and D.2.3. “Techno-economical possibilities and system correlations” of Decarb City Pipes already bring some pieces of practical answers to those questions. However, it is key for cities to understand how cost modelling works, what is a priority and why it is important.

When comparing the economic sustainability of individual solutions to district heating, cost modelling is invaluable, and, indeed, is the one way to determine whether DH is the solution for an area. Calculating the costs for individual systems is fairly easy: it is the sum of capital expenses upfront and operational expenses per a time period. For DH, however, the equation is a bit more complicated. A simple scheme illustrating this can be found in Figure 6 below.

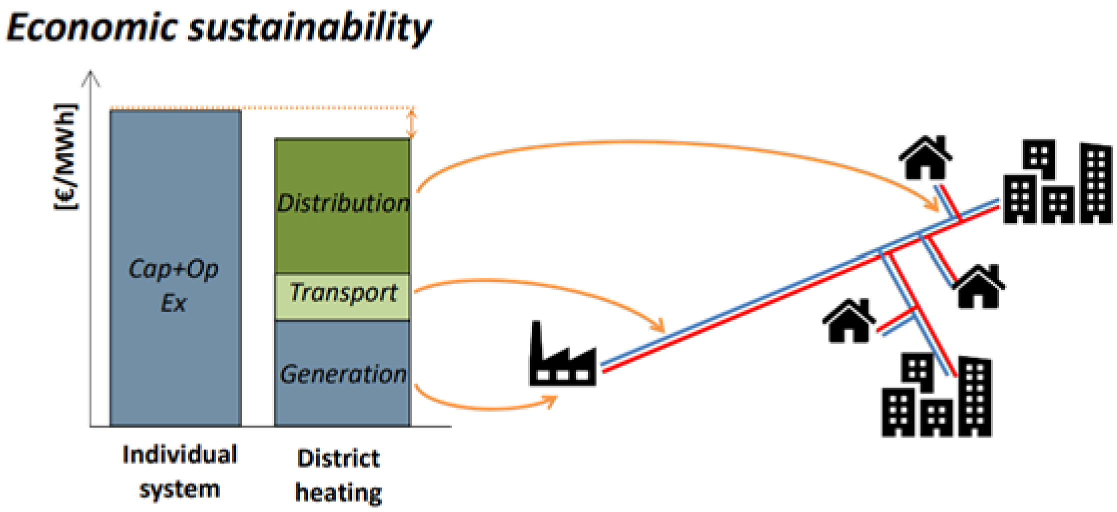


FIGURE 6: ILLUSTRATION OF THE COST MODELLING OF THE ECONOMIC SUSTAINABILITY OF DISTRICT HEATING

In this case, there are three main cost-efficiency drivers: a lower temperature system, the zoning, and high connection rates. The heat distribution is mostly where the devil lies, as this is the key additional cost component in comparison with local heat generation, and thus the one to be examined closely. The main factors affecting it are heat demand density – installing pipes is costly and would not make sense in the countryside – and the specific investment costs. Therefore, heat demand mapping with a spatial component (i.e., population density) of a high resolution is of the utmost importance and will determine the feasibility of DH and, thus, indirectly also large-scale heat recovery projects. Access to data is once again a key factor in cost modelling.

Case study: the City of Milan

The City of Milan has confronted itself to the exercise, with the aim of making a transition from fossil building-scale heating system to renewable solution at district scale. Politecnico Milano, in charge of the project, has calculated the potential diffusion of DH in the area, comparing costs of individual systems vs. district heating. It is a big challenge to estimate the cost of something which does not exist yet. To be as close as possible to reality, Politecnico Milano collected as much data as possible on the potential heat sources, compared the different heat taxes between the surrounding cities and set up a stakeholder group to estimate the cost of those potential developments.

The next step was the conversion of the heat map into a heat distribution map, looking for the best methodology to find the minimum cost delivery heat while matching heat demand and heat sources. This minimisation was the base of the modelling, which can be summarised in five steps:

1. Mapping the heat demand
2. Mapping the potential connection to the district heating system
3. Mapping the mostly dense heat demand
4. Having an overlap map of heat sources
5. Analysing the results

Thanks to this, the City of Milan found out that out of the 11TWh of demand, 70% was connectable to the DH system, but only 22% could be economically delivered by it, since subsidy schemes are still mostly for gas.

The benefits of planning

In the context of district heating (DH), modelling is important for two reasons:

1. To look at the current situation (*i.e.*, existing infrastructure, heat demand and supply density, available resources, etc.) and to plan the potential expansion of the network.
2. Since DH usually presents large and long-term investments, cost modelling of said expansion can easily be said to be one of the major criteria when it comes to evaluating its possibility and, therefore, deserves its own examination.

With plans of the European Commission to implement mandatory heat planning for cities above 50,000 inhabitants as part of the Energy Efficiency Directive (see more here), heat planning is *en route* to becoming even more important for local governments.

The German region of Baden Württemberg is already going one step further, making heat planning mandatory for cities above 20,000 inhabitants. To facilitate the work of planners, the region has asked PlanEnergi & the Danish Board of District Heating to develop a toolbox, gathering guidelines and tips which can be adapted to various local situations. Per Alex Sørensen took part in the development of this tool and gave Decarb City Pipes 2050's consortium an overview of its potential.

There are four main phases in the planning process of this toolbox, which can be seen in Figure 7 below.

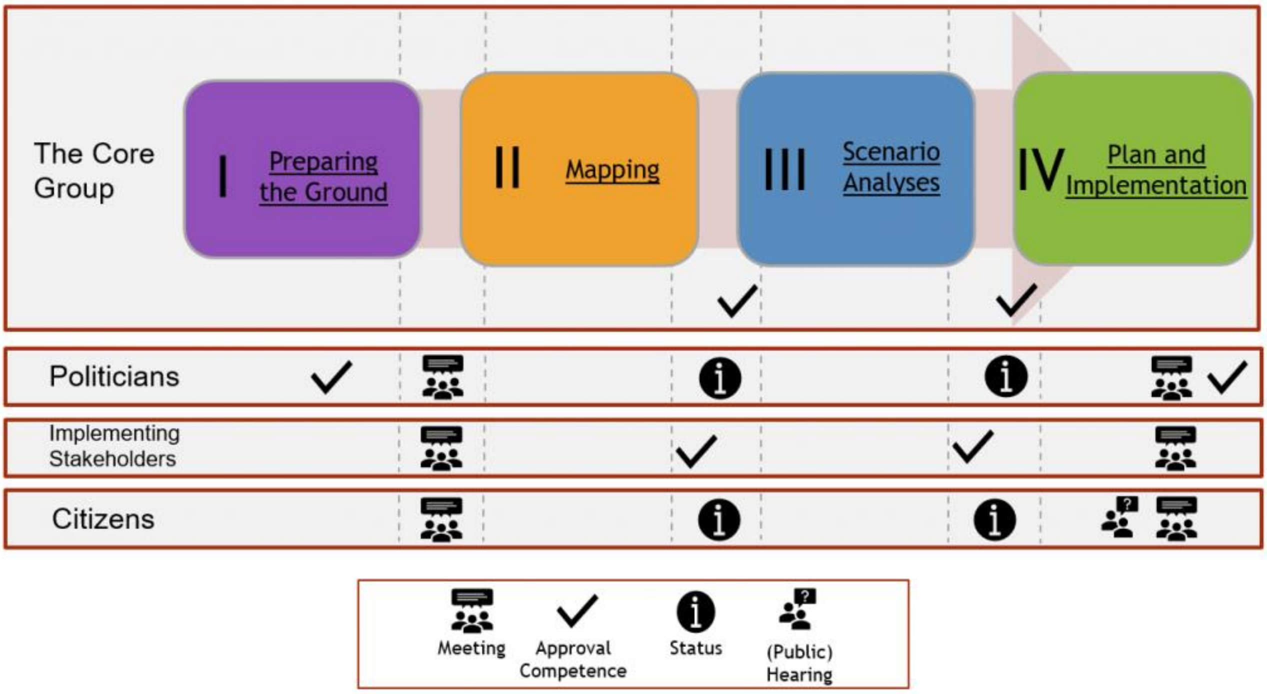


FIGURE 7: ILLUSTRATION OF THE DIFFERENT SECTIONS IN THE TOOLBOX

Each phase is further divided into several sub-steps including a list of the different stakeholders to be involved and the approval competences needed at the different stages. Best practices are also featured for each step, to give inspiration to the planners. Those examples are at the moment solely Danish, but the aim of the tool is to be personalised, thus slowly replacing the Danish examples with German cities (or from other countries, wherever the tool is to be used).

This aim of this toolbox is to be a living document, gathering several experiences. It is an example of bottom-up approach which highlights once again how crucial the access to data is, to make the tool as accurate as possible. It should be extended to other regions in Germany, and also in other countries.

One of the most underlined elements by both speakers and participants is that cost is heat demand density dependent. This session was also the opportunity to discuss different methodologies of modelling when data is not available, and to highlight once again how crucial access to the latter is.

The original article was published on the website of Decarb City Pipes 2050 on 17 December 2021. Presentations are gathered in the Library section of the website.

Conclusion

Main takeaways

- The main problems met by cities when discussing heating and cooling tools and techniques turn around three major topics: the access to data (for a good estimation of green gas potential, waste heat potential, cost-efficient modelling), the multiplicity of actors (public, private, citizens, etc…), and a proper cost-efficient evaluation of potential solutions.
- The argument supported by some stakeholders that green hydrogen could be a quick fix to solve the challenge of decarbonising heating systems is deceptive. Green hydrogen is not yet mature enough, nor cost-efficient, compared to existing solutions. It has thus an important lock-in effect which must be avoided. However, high-value energy sources such as green hydrogen may play a role in the decarbonisation of other sectors like heavy transport or high temperature industry.
- The most important element when looking at waste heat is for cities to reflect on how to contract with private companies for the heat recovery. The contract may include elements related to payback time, the possibility of an insurance scheme and also to foresee a backup plan if the waste heat source moves away. If not formalised, these elements should at least be considered when thinking of including waste heat to the district heating network
- Cost is heat demand density dependent: an accurate mapping of heat density is thus key in this process.

Next steps

- In Decarb City Pipes 2050, the tools and techniques which were presented should help cities with the establishment of their heating & cooling plans (task 3.5). The knowledge transfer should also support partners for the establishment of the roadmaps by each of the cities of the consortium.
- Those presentations should also be beneficial for cities outside of the consortium, since Decarb City Pipes 2050 aims also at favouring replication of good examples.
- The organisation of other capacity building sessions in the frame this project, on topics related to decarbonising heating systems, will provide the opportunity to maintain the connections which have been created. The idea of creating a community of exchanges
- Some cities already mentioned that they contacted the experts who gave presentations during the sessions. In addition, Energy Cities was contacted by a Belgian university who is interested in developing further the toolbox presented by PlanEnergi.

Annexes

Annex 1 – Encountered challenges

Challenge #1 – Finding a date which would suit everyone	
Observed challenge	14 cities in 7 countries, with different agendas, bank holidays and appointments.
Mitigation measures	- Proposing one date and see if a majority of cities are available, especially the ones who expressed a specific interest in the topic to be discussed. - If one of them would not be available, then a new date would be proposed. - Recording of the sessions for the absents.
Success rate	High. A good attendance rate from part of cities of the consortium.
Challenge #2 – Holding everything online	
Observed challenge	Initially, some of those trainings were planned in person, to favour formal but also informal exchanges between consortium members, sister cities, and experts.
Mitigation measures	- Each session was booked for two hours, to make sure that participants would have at least one hour for questions and exchanges with speakers. - Email addresses from the speakers, as well as presentations, were shared with participants. In addition, presentations are stored in the cloud of the project, so that cities who could not participate can still benefit from the exchanges. - Articles with key learnings are published on the website after each knowledge transfer session.
Success rate	High. Creation of a learning community, where questions and exchanges of information during the sessions were smooth.
Challenge #3 – Mobilising sister cities	
Observed challenge	Very little sister cities attending the knowledge transfer sessions
Mitigation measures	- Ask cities of the consortium to directly liaise with their sister cities to promote the event - Plan the session enough in advance to maximise chances of participation - Directly invite those for whom we have the contact details
Success rate	Mitigated. One sister city attended the last session.

Annex 2 – Overview of attendance

The main target audience of those sessions were cities, in priority those of the consortium, then sister cities, and then other cities. Detailed attendance can be seen in Table 3 below.

Session	# of city admin. staff	# of city admin. staff from sister cities	# of city admin. staff from additional cities
Green gases in decarbonised cities	25	0	5
Waste heat	9	0	4
Cost modelling	11	1	3

TABLE 3: DETAILED ATTENDANCE (CITIES)

Each session consisted of one to three presentations, each followed by Q&A time. Consortium members have been active in asking questions and to trigger the discussion with the invited experts.

The first session saw a majority of consortium staff attending and is also the only one of the series which was attended by a utility. This can be explained by the tackled topic, green gas, whose role is intensively discussed at various political levels, and which is a prime concern for utilities.

The following sessions have attracted a more diverse audience, with still a solid base of consortium members since the sessions are first and foremost designed for them. However, there is an increase in the participation of other cities in the session. This is important data for the project since it also aims at showing the path to other cities and build a community of practice.

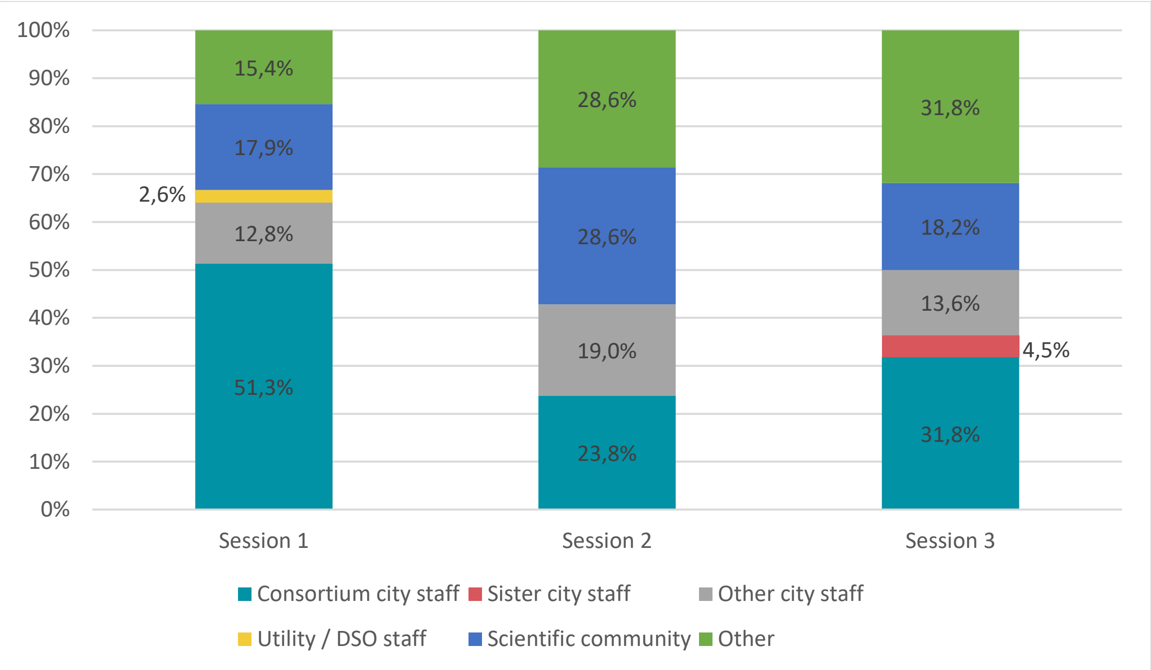


FIGURE 8: PARTICIPANT PROFILES

Annex 3 – Internal satisfaction survey

Evaluation of the capacity building sessions on heat mapping tools and methods

In the frame of Deliverable D.3.1, **Training of cities on H/C tools & techniques**, we would like to have your feedback on the three sessions which were provided:

- Green gases in decarbonised cities (March 2021)
- Waste heat (October 2021)
- Cost modelling (December 2021)

* Mandatory

1. Are you...*

○ A city member of the consortium

○ A sister city

○ Other

2. Please, specify:*

3. How many sessions have you attended?*

○ 1

○ 2

○ 3

4. What was the main reason for you not to participate in the other session(s)?*

- ☐ I did not see how to make my city benefit from the discussed topic
- ☐ I was not available at that time
- ☐ I was not aware that this session was held

5. Overall, how would you rate the quality of information received during the different sessions you attended?*

☐ ☐ ☐ ☐ ☐

6. Did the sessions inspire you to use new tools for heat mapping and/or planning?

- ○ Yes
- ○ No

7. Have you already started using them?

- ○ Yes, we already started using them
- ○ We haven't started yet but are in the process of implementing them
- ○ Not yet

8. Would you say that those tools and techniques presented during the different sessions were…

	Very relevant	Relevant	Not really relevant	Not relevant at all
Exploring the place of hydrogen in the city strategic planning	○	○	○	○
Contracting with industry for waste heatintegration in DH networks	○	○	○	○
Technical aspects of theuse of waste heat	○	○	○	○
Cost modelling techniques	○	○	○	○
Toolbox for heat mapping and planning(as used in Baden-Württemberg)	○	○	○	○

9. Would you agree with the following information?

	Totally agree	Agree	Have no opinion	Do not really agree	Do not agree at all
The tools and techniques presented were the main added- value of the session(s)	○	○	○	○	○
The feedback from the ground of other cities was the main added-value of the session(s)	○	○	○	○	○
The possibility to establish new contacts was the main added- value of the session	○	○	○	○	○

10. Following one of several session, have you initiated contacts with external experts / a presenter / another city who attended the session? *

○ Yes

○ Not yet, but I will

Annex 4 – Survey results

To measure the impact of the organised sessions, Energy Cities ran an internal survey by cities of the consortium and sister cities. It was answered by 3 of the 7 cities part of the consortium, 1 policy maker,1 LOI partner, and 1 forgot to mention that they are a city.

The aim of the survey was to:

- Better understand why some partners did not attend some sessions
- The quality of the information which was shared by the experts and the relevance of the tools and techniques presented
- The will it triggered amongst cities to start using new tools for H/C mapping and/or planning
- To what extent those sessions participated in creating a sense of community amongst participants.

We chose to only focus on respondents who are cities since they were the main target audience of the task. The average grade for the three sessions was of 4.75/5.

Only of respondent attended the three sessions, but all confirmed that the knowledge transfer activities inspired them to use new tools for heat mapping and/or planning, and half of them are already implementing or in the process of implementing one or several of the presented tools, as shown in **Fehler! Verweisquelle konnte nicht gefunden werden.**.

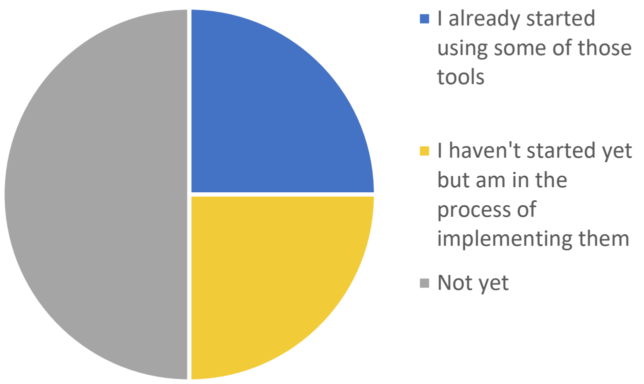


FIGURE 9: USE OF THE PRESENTED TOOLS & TECHNIQUES

All sessions were deemed either very relevant or relevant, with a slight preference for questions of technical aspects of waste heat, waste heat integration in DH networks and cost modelling techniques, as shown in Figure 10 below.

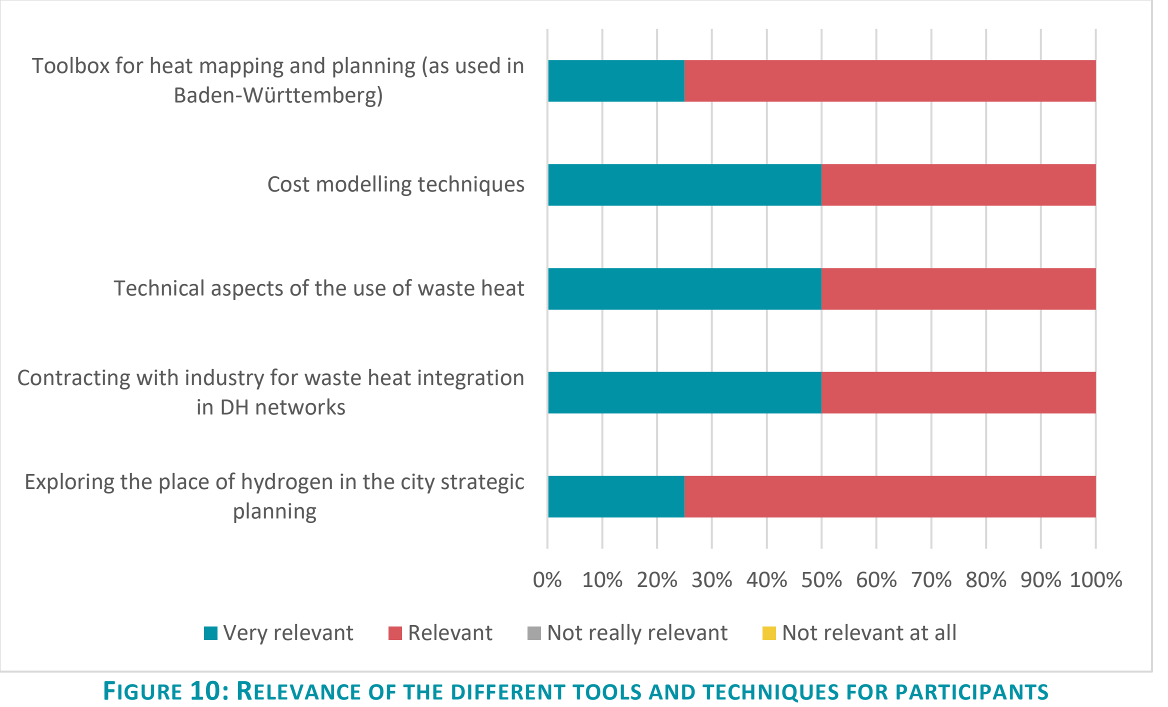


FIGURE 10: RELEVANCE OF THE DIFFERENT TOOLS AND TECHNIQUES FOR PARTICIPANTS

Figure 11 underlines that the clear main benefits of those knowledge transfer sessions for participants were not necessarily the presentation of tools and techniques as such, but the feedback from the ground of cities and experts using or developing those tools. Only one city does not plan to initiate follow-up contacts with external experts.

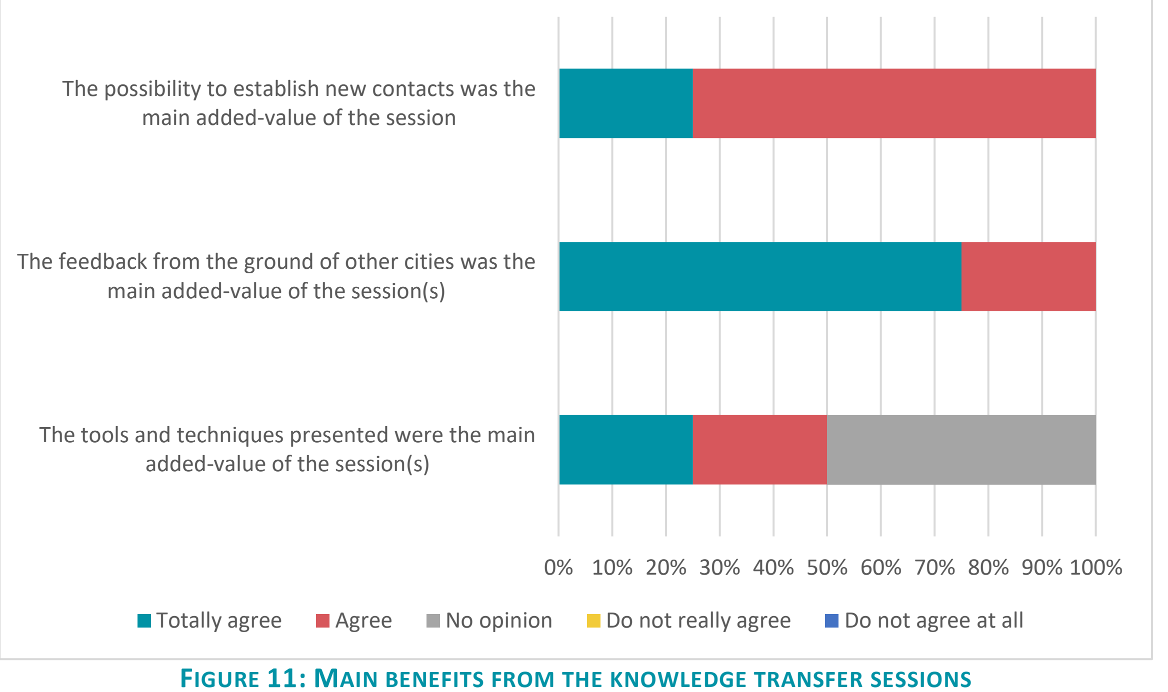


FIGURE 11: MAIN BENEFITS FROM THE KNOWLEDGE TRANSFER SESSIONS

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