European Commission

Benchmarking for mobilising investments in energy efficiency

ENER/C3/2017-442 – Topic 3
Developing efficient district heating to improve energy efficiency and security of supply

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1. Executive summary

The purpose of this report is to present and explain the results of the work done for topic 3 of the benchmarking for mobilising investments in energy efficiency project.

This study aims to provide Member States and associated key stakeholders with an overview and analysis of different DH systems. Specifically, it aims to:

- Identify and generalise key success factors for different DH projects.
- Benchmark the case studies against national averages.
- Develop policy recommendations.

The study should help to improve current practices in Member States and at the EU level.

For this purpose, topic 3 selected and analysed five case studies, comparing different district heating projects in different EU Member States, and derived key success factors.

Topic 3 heavily relied on the involvement of the topic's Steering Group, which consisted of 12 members from different EU Member States and different areas of expertise. After being selected through the EU-wide online survey, the Steering Group members joined three Steering Group meetings where they had chance to: (a) select case studies to be analysed; (b) propose and select criteria and indicators for the case study analysis; (c) provide feedback on the benchmarking methodology and the results of the case study analysis; (d) discuss and suggest policy recommendations originating from the case study benchmarking; and (e) participate in extensive knowledge sharing as another important target of the topic 1 and benchmarking project.

Following the initial ranking of proposed case studies in the first Steering Group meeting, topic 3 analysed five case studies:

1.1 Summary of the selected case studies

Five cases studies were analysed for topic 3, district heating (DH). The study's aim is to have a diverse set of cases that cover different geographical areas, history and country backgrounds, and technical solutions. The studies consist of both renovation and new construction cases.

1. Wastewater heat pump, Austria

In Vienna, Austria, a DH grid already exists, and the current share of DH is 35%. The heat is mainly generated via combined heat and power (CHP) and gas. This case study is about waste heat utilisation from the wastewater of the main sewage treatment plant in Vienna. It will be implemented until 2022. The first phase of the project is planned to be 55 MW (37 MW_{th} (wastewater) and 18 MW_{el} (hydro), and the second phase aims to double that value. The target is to increase the renewable energy for DH to 40% in 2030 (from 18%).

The main challenge is the diverse needs of the DH portfolio and meeting the long-term targets. Key for the project's success is that it is backed by strong political support, good economic conditions, and planning security.

2. Tartu district heating and cooling (DHC) system, Estonia

Tartu has a medium-sized DH system, which has been modernised and expanded with a focus on low carbon heat sources (bioenergy, waste heat). It includes the first district cooling (DC) system in the Baltics and Eastern Europe. Measures on the demand side have started as well (test of low temperature DH).

When looking into ownership and stakeholder involvement, there is a strong collaboration between the city of Tartu and Fortum, the DH supplier. The city has continuously integrated DH in planning, and Fortum collaborates with local industries.

In terms of success factors, the DH price level is competitive, there is continuous communication on the benefits of DH, and the project has strong support from local authorities. In terms of the main challenges, the District Heating Act and tariff regulation do not promote efficiency investments in DH systems.

3. Espoo Clean Heat, Finland

The Espoo Clean Heat initiative is a collaboration between the city of Espoo and Fortum to modernise an old DH system towards carbon neutrality. The system heavily depended on coal. The first phase is running till 2022 and 40% carbon reduction is expected to be achieved. When complete, the system will be highly diversified (biomass, thermal storage, heat pumps, etc.) and somewhat decentralised, replaced by a few smaller systems. The system is slowly moving to demand-side management. It will be a two-way DH system where excess heat comes from a hospital and small data centres.

Regarding success factors, Espoo has a green vision that is constantly communicated at the city level and from Fortum on different channels; whenever there is a new initiative, there is strong support from the city level. One challenge is decentralising the supply—it requires more space, especially for a geothermal plant, so it needs to fit in the urban picture.

4. Mórahalom cascading geothermal DH system, Hungary

In the project, 12 public buildings are heated by a geothermal DH system. The city was active in attracting funding nationally and at the EU level, achieving 50% to be funded. Small CHP units use geothermal methane (CH_4), and a heat pump uses residual geothermal heat. Buildings have undergone energy optimisation because they need the energy upgrade to handle lower temperatures. Some buildings have solar collectors.

Compared to the previous system, both CO_2 emissions and costs have decreased substantially, leading to a stronger economic position of the municipality.

5. Waste heat from data centre, Ireland

Running until 2021, the project is about heat supply from waste heat from a data centre extension with heat pumps. Almost no DH exists in Ireland, so this is an important pilot project to prove the concept in the country because it can be replicable to many other data centres in Ireland.

An important success factor is the competitive heating price and less emissions compared to the business-as-usual (BAU) case (gas boilers).

A challenge of this case study was convincing the municipality to become involved and be a driver of DH. However, secured funding and peer-to-peer funding from EU projects helped get the municipality on board.

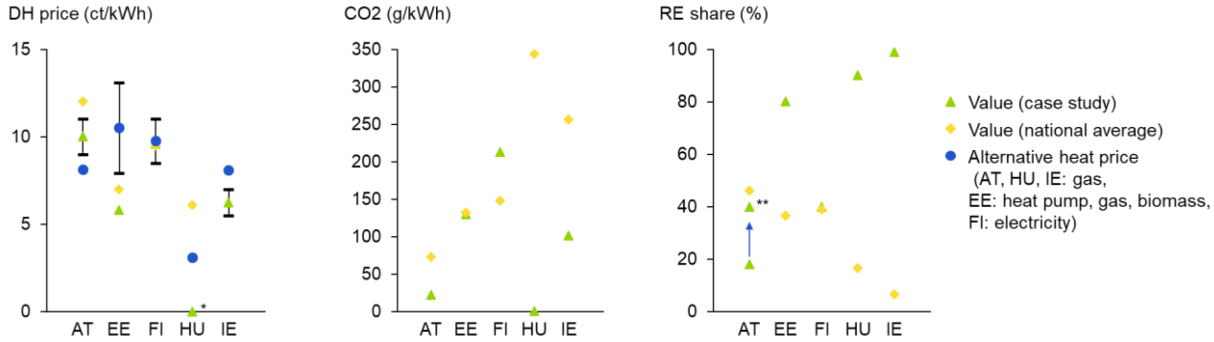
1.2 Benchmarking

The case studies are quite diverse, and a strict benchmarking may have led to conclusions that would be hardly comparable due to different project constellations (size, technology, financial framework); consequently, a ranking among the different projects would not have been meaningful.

Instead, it was agreed with the Steering Group and the European Commission that the result of applying a benchmarking methodology should not be a ranking between the different projects and countries but rather a comparison of key project indicators (case study) with national averages. Key indicators such as CO_2 emissions, DH price, and share of renewables and the benchmark case study key parameters have been analysed and benchmarked against national averages.

Figure 1 illustrates the results of this benchmarking.

Figure 1: Overview of case study key parameters benchmarked against national averages



* The DH price for Mórahalom (Hungary) is zero because the system produces heat for self-consumption in municipal buildings. Still, there are certain costs for the DH system (Heves, 2019 & 2020).

** In Austria, the renewable energy share improved from18% to 40% within the case study. The national average is mainly influenced by rural biomass (Griessmair-Farkas, 2019 & 2020).

*** CO_2 emissions in Espoo (Finland) are currently higher than the national average, due to the higher share of coal in the local district heating system, which however, has been decreasing substantially since 2016. It is expected that this parameter will improve further in the next few years as more and more coal is being phased out of the Espoo district heating system.

The information is based on personal communication and discussion during the steering group meetings (Heves, 2019 & 2020) (Kuusela, 2019 & 2020) (Luomala, 2020) (Keskivali, 2020) (Griessmair-Farkas, 2019 & 2020) (Gartland & O'Shea, 2019 & 2020) (Steering Group, Second steering group meeting, 2020) (Steering Group, Third steering group meeting, 2020).

Heat prices

In the left graph, DH prices from the five cases are benchmarked against national averages for DH prices and the most common alternative heating sources. Price intervals are given in the case of several common alternative heat sources in a country or local and national price differences (for alternative heat sources). The DH prices in the cases are generally competitive in a national context for all countries; however, the values also indicate that the competitiveness in relation to alternative heat prices heavily depends on context. This is because, for example, natural gas prices can differ by a factor of 3 between Member States (Eurostat, 2021) and also because relatively cheap alternatives are common in some countries (e.g. electricity and heat pumps in Finland). Overall, the figures indicate the cases are quite competitive, especially when considering their relatively good performance in terms of CO_2 emissions and renewable energy share compared to the national context and also with a view to an increasing CO_2 price in the future.

In Ireland, no national DH price data was available, presumably due to the relatively new status of the technology.

CO_2 emission factor and renewable energy share

Figure 1 illustrates that CO_2 emission factors in the case studies are below (Austria, Hungary, Ireland) or on par (Estonia) with the national averages for DH. Only in the case of Espoo in Finland is the CO_2 emission factor higher than the national average. However, this will change by 2026 if the Espoo Clean Heat initiative is implemented according to plan. In terms of renewable energy shares in DH, three of the cases (Estonia, Hungary, Ireland) perform significantly better than the national average or at the same level (Finland). Only the Austrian case (Vienna) has a slightly lower renewable share than the national level, on the other hand, is the highest among the five national averages due to high shares of biomass in Austrian district heating systems (close to 50%) (BMK, 2020).

1.3 Key success factors

The success factors have been based on the analysed cases and discussed with the Steering Group (Steering Group, Second steering group meeting, 2020). The success factors can be allocated to five main categories:

1. Policy framework
2. Stakeholders, key drivers, and interplay
3. Political will and support
4. Positive vision and image
5. Economic aspects

Each of the main success categories contain several aspects:

Policy framework relating to the EU and national levels

Clear targets are important for setting a (long-term) direction for the development of a DH sector. Targets specifying the renewable energy share or CO_2 emissions reductions are well-functioning examples but targets directly addressing DH expansion have also been used. Integrating DH into local and national decarbonisation strategies to increase the renewable energy share in the heating sector can also be an effective political tool. Favourable investment and planning frameworks for DH are essential for expansion. Successful examples address both the competitiveness of DH and the expansion of low carbon DH. A connection requirement or preferred areas (zoning) for DH networks (where competitive) have provided planning and investment security. Customer protection (especially in the case of mandatory connection to the network) by regulating prices and profits has been essential for maintaining trust in DH.

Stakeholders, key drivers, and interplay

Especially at the local level, identifying stakeholders and their key drivers and interests has been important for establishing successful collaborations around DH. Cities are often important key stakeholders with different roles in different contexts—e.g. as strategic planning entities, permitting authorities, operators of DH systems, and suppliers of waste heat. In successful DH systems, there is often a productive interplay and collaboration between local authorities, operators, and industries.

Political will and support

Local political support is important for processes, approvals, providing space for equipment, and DH zoning. Local funding can be an important driver and local political support for long-term use of DH is important due to the high upfront costs and long lifetime of DH infrastructure.

Positive visions and image

Strong positive visions and narratives for DH follow from supportive political frameworks and successful local collaboration and are important for maintaining a positive image—e.g. DH as a key technology for decarbonisation, bringing renewable energy cost efficiently to the city. Success stories and pilot projects help build positive narratives. The Vienna large-scale heat pump (HP) with 40 GW is a good example. Cities and district operators can also benefit from consistent and continuous communication about the advantages of DH. Direct engagement with local building owners can help build trust and spread knowledge (e.g. regarding the benefits of a low carbon DH supply).

Economic aspects

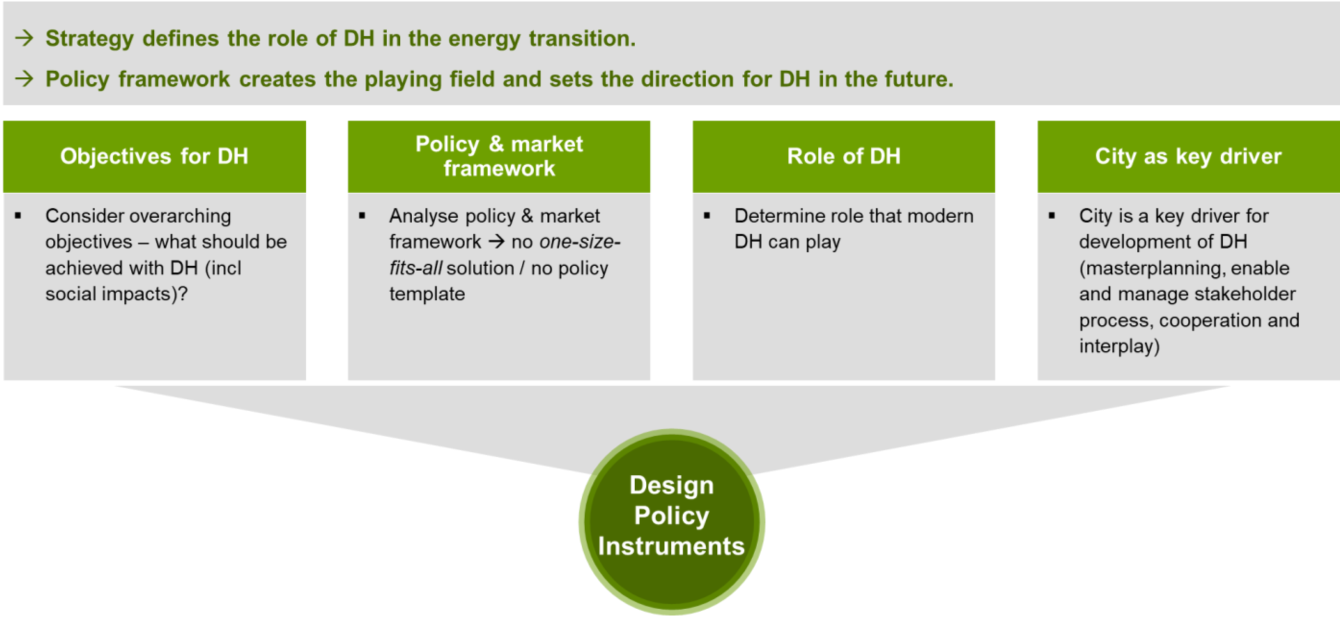
Funding has been important for establishing new DH networks. Prior to that, funding was also crucial to expanding the knowledge of funding possibilities. In the case study from Hungary, the DH project supporting the local economy is an important co-benefit. Successful projects thrive on planning security for long-term investments by means of long-term contracts. Another key success factor is if the investment cycles of the operator are matched (investments in renewable energy together with upgrades of old production infrastructure). From an operator perspective, diversifying the portfolio by investing in renewable heat sources increases the economic robustness of the system because it decreases the system’s dependence on gas or oil (prices).

1.4 Policy recommendations

The developed policy recommendations are based on broad discussions that happened mainly in two meetings (Steering Group, Third steering group meeting, 2020; Steering Group, Second steering group meeting, 2020). For the development of the policies we have followed a two-step approach, where in a first step, key aspects for policy recommendations had been identified and, on this basis, recommendations along these key aspects had been developed.

Relevant aspects for designing polices are the overarching objectives and possible contribution of DH to these objectives, the policy and market framework, the role DH can play in general, and the city as a key driver for the development of DH. Figure 2 gives an overview of the relevant aspects for the design of DH policies

Figure 2: Illustration of relevant aspects for the design of DH policies



The policy recommendations had been developed and broadly discussed with the Steering Group. It has been decided to group the recommendations in the following categories: targets, strategy and planning, policy and market framework, financial incentives, information and governments (Steering Group, Second steering group meeting, 2020) (Steering Group, Third steering group meeting, 2020).

The following tables present the summary of the policy recommendations along these categories. The detailed policy recommendations are presented in chapter 7.2.

Target, strategy and planning	EU	MS	City
Embed DH in energy strategies and climate plans	✓	✓	✓
Include DH in scenario calculations, including social benefits	✓	✓	✓
Include the transition to zero carbon DH	✓	✓	✓
Set renewable energy and CO_2 emissions targets for DH		✓	✓
Strengthen role of DH in smart grid and flexibility considerations	✓	✓	
Introduce requirement for green local heat plans		✓	
Consider DH zoning and possibly mandatory connection depending on the policy framework		✓	
Introduce city heat planning			✓

Market regulation	EU	MS	City
Equal playing field			
Ensure equal playing field for DH and other technologies	✓	✓	
Ensure uniform treatment and accounting of DH	✓	✓	
Design regulation in the context of the whole energy transition	✓	✓	
Different regimes			

Market regulation	EU	MS	City
Introduce policy instruments for the transition to efficient and zero carbon DH		✓	
Monitor DH prices and ensure transparency		✓	
Introduce price control mechanisms		✓	
Ensure adequate incentives for improving energy efficiency of the building mass		✓	
Ensure consumer protection		✓	
Facilitate ownership power by enabling public ownership of DH systems		✓	✓

Financial instruments	EU	MS	City
Increase efficiency of DH, decarbonise DH	✓	✓	
Foster stakeholder cooperation	✓	✓	
Develop masterplans	✓	✓	
Provide technical assistance	✓	✓	
Elaborate heat map		✓	
Execute feasibility studies		✓	
Integrated projects: building renovation and (low temp) DH expansion		✓	✓
Low temperature DH (in newcomer countries)	✓	✓	
Citizen / private public partnership (PPP) DH projects		✓	✓

Governance/information/transparency	EU	MS	City
Monitor progress with transparency and information availability in the DH sector; develop metrics and parameters (cost and prices)	✓	✓	
Make sure the calculation rules, assumptions, and data support a low carbon 2050 energy system and not the status quo of today		✓	
Streamline methodologies (e.g. primary energy factor), improve data availability for project assessment	✓	✓	
Ensure DH cost and price transparency		✓	
Ensure consumer rights		✓	
Maintain long-term collaboration with DH companies supported by exchange of information			✓
Be representative in DH company boards (if granted by national government by ensuring transparency)			✓

2. Objectives

District heating (DH) networks are well-established technology options for providing heat to buildings. Most of the 6,000-plus DH (and cooling) systems can be found in Northern, North-eastern, Eastern, and Central Europe. This study aims to provide Member States and associated key stakeholders with an overview and analysis of different DH systems. Specifically, it aims to:

- Identify and generalise key success factors for different DH projects.
- Benchmark the case studies against national averages.
- Develop policy recommendations.

The study should help to improve current practices in Member States and at the EU level.

3. Methodology

3.1 Selection process

A thorough primary literature review and questionnaires sent to DH experts provided our initial understanding of the characteristics of these case studies and served as the basis for our benchmark of the different case studies. This review included scanning relevant programmes and projects related to energy efficient DH through desk research. This way of consulting the market and existing literature results in a list of potential case studies that were further filtered to identify the cases for the benchmarking analysis.

Identifying potential case studies

The selection process was divided into two steps: an exhaustive literature scan and inputs from the questionnaire participants.

Exhaustive literature review

- Project homepages and project reports, including:
  - progRESsHEAT project
  - Heat Roadmap Europe 4 project
  - CELSIUS project; *Efficient district heating systems in the EU study* by JRC (2016)
  - *Future Green Buildings – A key to cost-effective sustainable energy systems* study
- Research networks (Heat Roadmap Europe projects; 4th Generation District Heating)
- Scientific publications
- DH company homepages
- Research on the District Energy Award website (https://www.districtenergyaward.org/)
  - Screening of 121 applications and award winners between 2009 and 2017
  - Prioritisation of focus countries and types: modernisation, new schemes, multi-family houses, etc.
  - Good overlap with project objectives (from the 2013 edition of the District Energy Awards):
    - *Identifying & recognizing systems that illustrate the overall importance of DE in providing sustainable energy solutions.*
    - *Providing a global benchmark for environmental excellence.*
    - *Offering a platform for sharing successful ideas and efforts and encourage further interest in district energy.*

Inputs of survey participants on possible case studies

The questionnaire was sent to relevant contacts within national and EU DH company associations, DH companies, and DH professionals. The questionnaires asked for examples of DH programmes or projects that the contacts consider to be leading practice examples for DH energy efficiency improvement with potential to be copied to other Member States.

Individual contacts could determine what they consider good case studies in their Member State. The study team specifically asked the contacts to be explicit as to why they think their suggested case studies should be further investigated.

Long list (20 cases)

In a first step, the cases had been filtered by three criteria. First, data availability is key, and a large part of the data availability directly depends on the participation of relevant contacts from the questionnaire. Therefore, willingness to share information and data availability was one of the primary criteria for selecting cases for further analysis and benchmarking. Second, it is indispensable that a project has resulted in an improved emission factor (in the renovation case) or in comparison to standard (in the new construction case). Third, a case should be somehow replicable for a project or programme in a similar situation to allow for learning and illustrating leading practices. This excludes pilot and very sophisticated solutions. In summary, the following criteria were applied to the potential case studies identified to filter out 20 suitable case studies (comprising the long list):

- Data availability and willingness to share data
- Improved emission factor (renovation) or in comparison to standard (new construction)
- Project size (no pilot project)

Medium list (10 cases)

The 20 case studies on the long list were checked against several criteria during a more detailed analysis, resulting in 10 case studies. The following criteria were applied - four of the eight criteria needed to be fulfilled:

- Competitive price
- Multifamily buildings targeted
- Share of renewables
- Reduction of heat losses in network (in kWh)
- Embedded in larger policy programme (city or national programme)
- Innovative element (social, technical, environmental, economic)
- Involved stakeholders (city, utility, industry, others)
- Replicability potential

DH projects are local by nature and depending on the specific project. The challenges that certain projects face may differ substantially. Thus, apart from the criteria per project, the final selection of the portfolio also had to take this into consideration. Representativeness on a portfolio level is important because it means that other projects can identify similar situations and learn from this project. The diversity of the selected cases highly increases the replicability on a portfolio level. For the selection of the 10 cases, this was addressed by confirming the portfolio is representative and complementary, combining diverse characteristics of the projects from a technical, urban, climate, and financial perspective.

These categories have been translated into additional conditions to be fulfilled by the final group of case studies:

- **Geographical coverage:** At least two of the following EU regions should be covered in at least one case study each: south, central, and northern
- **Type of network:** Different types of energy supplied (i.e. heating or heating and cooling), different scales, different ages, new or existing
- **Market maturity:** Different status of market maturity, ideally from non-existent to mature
- **Availability of different sources of heat supply:** e.g. co-generation, waste heat from industry, renewable energy (geothermal, solar, biomass), heat pumps, thermal storage, etc.
- **Economics of the project:** Absolute DH prices for the customer and relative prices for DH compared to oil, gas, and electricity, depending on subsidies
- **Other aspects:** Social impact, innovative elements, density of area
- **Regulatory framework:** Cases should reflect situations with no regulation, a heat market with nationally centralised regulation, and different levels of city planning (e.g. zoning).

Table 1 illustrates the result of the filtering process for the medium list.

Table 1: Medium list (after filtering)

Location	Key Words
Estonia (Tartu)	Large/medium, old, modernisation, DH-DC-CHP, smart meters, almost 100% renewable energy
Denmark (Brædstrup)	Solar thermal, Heat pump (HP), electric boiler, seasonal storage, demand-side management, small scale, consumer-owned
Poland (Poznan)	Modernisation, expansion, CHP, building renovation, renewable energy (biomass)
Germany (B.-Bissingen)	Integrated energy concept (new housing area with reduced heat and electricity demand, CHP, biogas)
Ireland (Dublin)	First public sector energy performance contracts (EPCs) in Ireland. First DH system in Ireland using a performance-based heat supply contract (leading practice: contracting and facilitation process)
Austria (Vienna)	Heat from wastewater
Hungary (Mórahalom)	Cascading geothermal network, measures for energy efficiency and renewable energy
Finland (Espoo)	Large, biomass, waste heat, two-way DH, DC
Sweden (Stockholm)	Creating a market for recovered energy
Denmark (Tilst)	Low temperature, smart meters

These 10 case studies were then presented to the Steering Group members. In a group discussion, five out of these 10 cases were selected for the benchmarking analysis.

3.2 Final selection (outcome of the workshop)

Pre-selected case studies were discussed and further developed by any Steering Group members involved in the project or programme. Participants were invited to discuss the benchmarking methodology, which brought up a fruitful discussion on criteria and indicators. Steering Group members then voted on the cases most interesting to them or this study.

The cases were presented partly by the consortium and partly by the stakeholders, who brought their own cases in the Steering Group meeting. Based on the presentation and extensive discussion five cases were selected.

The case studies are presented in detail in Chapter 5.

3.3 Benchmarking methodology and indicators

The following provides the indicators that have been presented, adapted, and finally agreed in the stakeholder meetings.

The case studies are quite diverse, and a strict benchmarking may have led to conclusions that would be hardly comparable due to different project constellations (size, technology, financial framework); consequently, a ranking among the different projects would not have been meaningful.

Instead, it was agreed with the Steering Group and the European Commission that the result of applying a benchmarking methodology should not be a ranking between the different projects and countries but rather a comparison of key project indicators (case study) with national averages. Key indicators such as CO_2 emissions, DH price, and share of renewables and the case study key parameters have been analysed and benchmarked against national averages.

A second step was to focus on case-specific key success factors, generalising them and making them accessible for different cases throughout Europe.

The results of this task are described in chapter 6.

The following are the concrete indicators for the benchmarking:

- National average DH price
- DH price in case study
- Heat price of standard heating fuel
- Share of renewable energies in DH national average
- Share of renewable energies in case study
- National average CO_2 factor of DH
- CO_2 factor of DH in case study

To summarise the case studies, the study team tried to collect additional information, such as:

- Type of supply (biomass, solar, geothermal, waste heat, CHP)
- Funding share
- Total investment
- Installed capacity
- Size of network
- Temperature levels
- Generated energy
- Network loss

- Supply source
- CO_2 and energy savings
- Market share
- Customers connected

4. Context

Figure 3 gives an overview of the legal context, policy initiatives, and leading practices as well as some examples of Member State regulatory approaches with respect to DH. The specific context is elaborated in the case study sections accompanied by Member State specific policy context

Figure 3: Overview of legal context, policy initiatives, and leading practices as well as some examples of Member State regulatory approaches

Legal framework

- 2012: EU Energy Efficiency Directive:
- Comprehensive national assessments of CHP and DHC (first cycle 2015)
- 2018: The National Energy and Climate Plans (NECPs)
- Second cycle due 31.12.2020

Policy initiatives

- 2016: First ever EU Heating and Cooling Strategy
- 2020: Renovation wave strategy 2020
- 2020: EU Strategy for Energy System Integration

--> e.g. "Accelerate investment in smart, highly-efficient, renewables-based district heating and cooling networks"

Leading practice and knowledge sharing

- Heat Roadmap Europe (since 2012)
- 2020: Best practice + policy recommendations for industry;

--> reducing heat demand and decarbonizing heating

Member State examples of regulatory approaches

- For profit markets:
  - Example: Sweden (50% DH); high share of municipal company and commercial ownership
- Non-profit markets:
  - Example: Denmark (60% DH of households); high share of consumer and municipal company ownership
- National tariff regulation:
  - Central and Eastern Europe; sometimes state monopoly in DH (and natural gas)

5. Case studies

The aim of the project is to analyse different DH systems and learn from the case studies to provide Member States and associated stakeholders with key success factors for different DH projects and develop policy recommendations to help improve current practices in Member States and at the EU level. To have a diverse set of cases that cover different geographical areas, history and country backgrounds, and technical solutions, the following five cases were selected (see Section 3.2). They consist of both renovation and new construction cases.

The case studies have been developed in cooperation with the Steering Group. Internal data from the case studies has been provided where possible to allow insights; the cases, their success factors, and policy recommendations have also been discussed intensively during meetings, and in bilateral communications.

The following sections present the case studies in more detail.

Table 2: Selected case studies (DH)

Location	Geogr. cover.	Regulatory framework	Type of network	Market maturity	Different heat sources	Economics of the project	Other aspects	Replicability
Estonia (Tartu)	NE	• Centrally regulated DH market • Legal framework for DH • District Heating Act (including DH price regulation) • DH price cap and DH reference price • Master plan with DH zoning • Mandatory DH connection for new and renovated buildings	Old, large, renovation	High	• Biomass CHP • Gas, oil, and biomass peak load boilers • DC plant: heat pump • Waste heat from paper industry	51.05 €/MWh (excl. taxes) (national average: 60 €/MWh)	DH and DC High share renewable energy	• Modernisation of large grids • DC • Combination of several aspects: renewable energy, DC, waste heat recovery
Ireland (Dublin)	N	• Developing evidence-based local-level energy planning policy for 6 years • A national-level policy framework for DH is just now being developed.	Small	Low	• Waste heat from data centre extension coupled with heat pumps	6 ct/kWh	Motivated industry to sell heat, performance-based heat contract	• First of its kind in Ireland • New way of contracting: fixed heat supply price and output-led specification
Austria (Vienna)	Central.	• No specific framework for DH	Large use of secondary system	Medium	• Integration of waste heat in DH system • Use of local heat sources for DH system		High density city	• Guideline for use of heat from sewer in urban area • Analysing of sector coupling aspects (system-based integration)

Location	Geogr. cover.	Regulatory framework	Type of network	Market maturity	Different heat sources	Economics of the project	Other aspects	Replicability
Hungary (Mórahalom)	SE	• National Energy Strategy 2030 • District Heating Development Action Plan • Mórahalom development policy	Small, new	Low	• Cascading geothermal network • Heat pumps • Renewables (biomass, solar PV, solar thermal) • CHP, using escape CH_4	Using funds in an optimal way	• Co-benefits • Social impact, reduce local vulnerability • Measures for renewable energy and energy efficiency	• Optimal way of using funds • Achieve financial sustainability and stronger local economy; more funds for further public investment
Finland (Espoo)	N	• No dedicated DH regulation, no promotion programmes	Large, two-way DH, DC	Medium	• Biomass, waste heat, heat pump, geothermal	€53-77/ month/ ap. DHC in competition with other heating solutions	Very modern (fourth generation), carbon-neutral target	• Many of the new technological approaches will be implemented in this scale for the first time

Source: (Gartland & O'Shea, 2019 & 2020) (Griessmair-Farkas, 2019 & 2020) (Heves, 2019 & 2020) (Kuusela, 2019 & 2020) (Novosel, 2019 & 2020) (Wanne, 2019 & 2020) (Steering Group, Second steering group meeting, 2020)

5.1 Wastewater heat pump in Vienna, Austria

5.1.1 Project context

Table 3: Key figures of the project

Funding (share %)	Total investment (total)	MW installed	km network	Tempera-ture levels	Energy generated (MWh)	Network loss	Supply source	CO_2 (tCO_2)	DH share	Customers connected	Customer price (€/MWh)
10-12%	>€50 million	37 MWth (wastewater) 18 MWel (hydro)	New: 3 km (existing 1,200 km)	72°C-90°C	130-440 GWh_{th} (Input GWh_{el} 42-144)*	9%	Increase share of renewable energy from 18% to 40% in 2020 (source: waste heat 67%, electricity 33%)	> 33,000 tCO_2/ year (up to 105,000)	35% (Vienna)	400,000+ flats, 6,800+ key account-customer	9-15 ct/kWh

* The coefficient of performance (COP) is in the range of 3. The operation hour depends mainly on the comparison between the heat generation costs of the heat pumps and existing heat generation portfolio (varies between 4,000 to 8,000 hours per year).

Source: *(Griessmair-Farkas, 2019 & 2020)*

5.1.2 Project summary

This case study presents a project in Vienna, which uses the heat from the main sewage treatment plant's wastewater as a heat source for a large-scale heat pump, which is then fed back into the existing DH system. The project is in execution until 2022. This type of project can be applied to sewage treatment plants that use the waste after the treatment process for decentral and central usage. The data input was provided from the *Association of Gas and District Heating Supply Companies (FGW),* Austria (Griessmair-Farkas, 2019 & 2020).

In Austria, DH networks play a central role in the future decarbonisation of the heating sector by enabling the integration of locally available alternative energy sources (e.g. waste heat from industry and commerce, wastewater, geothermal, and solar thermal energy) while simultaneously efficiently operating the infrastructure (e.g. reduced operational temperature level).

Around 35% of heat demand in Vienna is covered by a DH system with a pipe length of more than 1,300 km. The produced heat by the DH system varies between 5 and 6 TWh per year. The majority of produced heat is covered by gas-based CHP and waste incineration plants. The DH system is characterised by a renewable share of around 18%.

Wien Energie's strategy forces a diversification of generation portfolios to reach a renewable share of 40% up to 2030. Reaching the renewable target is based on the following pillars: utilisation of waste heat and geothermal heat in production; digitalisation of the DH system (smart heat grid), and reduction of the operational temperature level.

A main sewage treatment plant in Vienna (Hauptkläranlage EBS-Wien) is responsible for removing contaminants from the total municipal wastewater. After the treatment, the total wastewater will feed into Danube canal and after that the Danube River. The flowrate of wastewater (baseline) is in the range of 3,500-7,500 litres per second. The temperature level of the treated sewage fluctuates between 12°C and 25°C within the year. The use of heat in wastewater (it serves as the heat source) for the DH system occurs with large-scale heat pump technology with a technical potential of about 120 MWth. In the first project phase, heat pumps with a thermal output of approximately 60 MWth will be installed. The needed electricity for heat pump comes from a regional hydro power plant, which is near the location of the main sewage treatment plant and has a direct power line (no network charges, which is important). The output temperature of heat pump heating would be up to 95°C.

Financing and price structure

Detailed investment figures are not publicly available.

The benchmark of the economic feasibility is based on the comparison of the heat generation cost of the production portfolio with and without the mentioned use case or project. The difference of incurred generation costs is related to the analysed project and depicts the cash flow during the operation. In the next step, the net present value and amortisation duration can be derived based on consideration of fixed and investment costs.

The end-user prices in Austria for DH systems are, on average, between €90 and €150 per megawatt-hour (MWh). The price depends on installation costs, length of grid/energy density, heat generation costs, maintenance costs, and includes provider services (Griessmair-Farkas, 2019 & 2020).

The contracts are typical DH supply contracts (no changing in existing contracts).

5.1.3 Policy framework and support programs

Support and funding programmes: local, national, regional

The plant will be funded by the national (Wärme- und Kälteleitungsausbaugesetz/ Umweltförderung Inland) funding authority. National funding is submitted for the heat generator and the needed expansion of heat infrastructure in a range of up to 30% of total investment costs with a limited absolute value.

Regulation of the DH sector

In AT, the DH sector is not regulated. There is free choice of connection and no compulsory connection. In some cities, there are preferred areas for DH or high efficiency heating, such as Graz, Linz, and Vienna.

According to PreisG 1992 §3 Abs 3, § 8, the Minister of Economy and Employment may define by ordinance principles and structures of tariffs for DH-supplying companies. The Minister may further entitle federal authorities to implement this power—for example, an official order on pricing for Wien Energie enacted by the provincial governor of Vienna. In this case study, a long-term supply contact has been agreed on to use the heat from the wastewater. Following EU climate and energy policy, Austria is coordinating national and European legislation and is aiming to give to the national climate and energy policy a modern legal frame while implementing the EU law.

Government program: 2020-2024

For the first time, there is a coalition government consisting of the People's Party and the Green Party in Austria. On 2 January 2020, the government published a new program for the legislative period 2020-2024 titled Taking Responsibility for Austria (Austria Government, 2020). The new program should make Austria a pioneer in climate protection.

The ambitious objectives of the government program can be summarised as follows:

- 100% electricity supply from renewable sources by 2030
- Climate neutrality (not required until 2050 under EU targets) by 2040

Because electricity demand is only a fraction of Austria’s total energy demand, a further massive expansion of energy generation from renewable sources will be necessary from 2030 to 2040.

The phase out of fossil fuels for space heating is planned as of 2020—end use of all oil and coal heating systems by 2035, no new installation of gas-fired boilers in new buildings as of 2025, and developing a thermal strategy for a complete decarbonisation of the heating market. To support volatile renewable electricity generation (wind and PV), hydrogen technology will also be promoted. The government program calls for the development of a new Austrian hydrogen strategy.

The city of Vienna and Austria want to decarbonise in the midterm and consider DH an important instrument to decarbonise the heat in cities.

New Energy Act from 2020

A comprehensive New Energy Act (*Erneuerbaren Ausbau-Gesetz*) will ensure that objectives are achieved in terms of the development of renewable energy in Austria.

Hydroelectric power, wind power, and PV will be the driving forces behind that development. Biomass-fired electricity production is expected to make a limited contribution. The main potential of these energy vectors is in decentralised systems with heat-led CHP and in the heating sector. The New Energy Act intends to integrate all subsidy systems for renewable energy. No direct impact on DH.

Austrian Heating/Thermal Strategy

For the heating and cooling and transport sectors, no estimated target trajectories can be provided at this stage. This will require further detailed work, in particular the development of a heating strategy (*Wärmestrategie*) in collaboration with the provinces and the creation of a With Additional Measures scenario (WAM, first half of 2019). In any event, the measures in the government program call for avoiding the combustion of fuel oil, coal, and fossil gas for heating and cooling as far as possible. In addition, Austria's consistent anti-nuclear energy policy will continue. The heating strategy supports, among others, DH solutions.

Federal Energy Efficiency Act

The Austrian Federal Energy Efficiency Act (*Energie-Effizienz-Gesetz*) complies with the need under EU law to boost energy efficiency between now and 2020. Aside from the obligation schemes, a series of measures (e.g. regional residential building grants, energy and environmental grants, and federal funding instruments) are helping to improve energy efficiency. The national framework needs to be reconfigured for the period between now and 2030 to take account of developments within the EU in the energy efficiency sector**.** No direct impact on DH.

5.1.4 Ownership, process, and stakeholder involvement

The project has been initiated by Wien Energie, the local energy supply company. Wien Energie invests and operates the plant. The driver is to diversify the production portfolio of the DH system.

Involved stakeholders are Wien Energie (energy supplier and operator), Wien Kanal/ EBSWien (canalisation company and operator of main sewage treatment plant), Wiener Netze (grid operator, electrical and DH system, for planning and building the connections to the electricity and heat grids), various companies covering the technical lots, a funding agency, and various city authorities involved in the permission process.

The role of policy (makers) in this project is key. Without political support this project would not be possible. The operator of the sewage treatment plant is the city-owned company, and the city provided space in public space for (technical) equipment and has an effective process for obtaining permits when needed. In general, policy supports DH for long-term use because DH is an important part of the decarbonisation strategy and integrates the local renewable energy into the energy system of the city.

Key drivers of the main stakeholders for further investment are:

- Vienna has set a target to increase its share of renewables from 18% to 40% by 2030.
- The current portfolio needs to be diversified, getting a stable economic result within volatile and changing market conditions.
- Decarbonisation, which needs to be economical.
- Authorities are looking for approval of a unique project using regional resources,

5.1.5 Impact and Co-benefits

Table 4 gives an overview of the indicators that have been analysed and of the results. The table allows a benchmarking of the following project-specific data and national average data per indicator:

- DH heat price
- Heat price (e.g. gas)
- Share of renewable energy
- CO_2 factor
- Temperature level (delta between flow and return temperature)
- Size of network

Table 4: Benchmarking against national average

Indicator	Case study	National average
DH price	Mix of different tariffs with different price components. Probably price is on the lower end of national average.	The end-user price is, on average, between €90 and €150 per MWh (DH system)
Price of standard fuel for heating (gas in Austria)	-	Energy price for end-consumer (households) from €45 to €85 per MWh (tarifkalkulator, 2020)
Share of renewables in heat generation	Increase from 18% to 40% in 2020 (renewable or alternative heat resources like waste heat and geothermal heat)	Renewable share in DH system in Austria is about 46%. It comes mainly from using biomass in rural areas.
CO_2 emission factor of the project compared to national average (DH)	CO_2 emission factor of DH in Vienna: 22 g/kWh	CO_2 average emission factor of DH 90-95 g/kWh. (OIB Richtlinie 6 , 2019)
Emissions savings compared to BAU	33,000 tCO_2/year (up to 105,000) depends on full load operation times. CO_2 savings compared to standard case (gas heating).	N/A
Heat losses in network	9%	
Temperature levels in network	72°C-90°C	N/A
Size of network	>1,300 km (existing), 3 km (new)	N/A

(Griessmair-Farkas, 2019 & 2020)

Co-benefits

The case study shows several co-benefits such as a possible transfer of expertise with a guideline regarding planning, installation, and operation of such plants; the integration of waste heat in a DH system; and the use of local heat sources for the DH system. On the basis of this project, a guideline for utilisation of heat from sewer in urban area has been developed and may serve other similar projects (Griessmair-Farkas, 2019 & 2020).

5.1.6 Success factors and barriers

The analysis of the case study revealed the following key success factors and barriers:

- **Stakeholders involvement:** A main success factor was to identify and involve the main stakeholders.
- **Long-term planning:** The case study revealed that the long-term contract securing Wien Energie access to and use of sewage water as a heat source for the heat pumps was a key aspect to success. Without this contractual assurance, Wien Energie would probably not have taken the risk to invest in heat pumps.
- **Political support:** The operator of the sewage treatment plant is the city. The project would not have been possible without the city, because it facilitated public space for (technical) equipment, an effective process for obtaining permits when needed. Additionally, there was clear political support for long-term use of DH, because DH plays an important part of the decarbonisation strategy of Vienna and Austria. The city and the country want to decarbonise on midterm and see DH as important instrument to decarbonise the heat in cities. Therefore, DH must be decarbonised, and the investments in carbon-free technologies are in line with the city/country strategy.
- **Economic aspects:** The local electricity provision from the hydro plant allows saving electricity grid fees and supports the business case. The planning security (from an economic point of view), with 50 years of wastewater usage agreement (more than 50 million EUR invested) is high. No compulsory connection exists; however, there are preferred areas for the heating network. The price for DH is competitive in Vienna (in comparison to the competitive technologies), and the project fits into the investment cycle when considering the lifetime of the existing production units.
- **Image/communication:** In Vienna, there is already a large heat pump (HP) of 40 GW (largest plant in middle Europe), which is a success story that supports a positive vision of DH.

5.2 Tartu DHC system, Estonia

5.2.1 Project context

Table 5: Key figures of the project

Funding (share %)	Total investment (total)	MW installed	km network	Tempera-ture levels	Energy generated (MWh)	Network loss	Supply source	Energy (MWh)	CO_2 (tCO_2)	DH share	Customers connected	Customer price (€/MWh)
100% private capital (Fortum, Banks)	N/A	303	194 (DH) 6 (DC)	105/55°C (winter) 75/48°C (summer)	520,000 (sold)	10.8%	80% woodchips, wood waste 17% peat 3% natural gas	N/A	2008-2019: 52%	50% (of buildings)	1,938 (70,000 end users)	Applied price: 58.20 (incl. VAT)

Source: (Külaots, 2020)

5.2.2 Project summary

The project covers the modernisation of the Tartu DH system, with a focus on the period after 2008. It involves a combination of different technical solutions, including the shift to (regional) biomass in the DH system and the phase out of fossil fuels; the utilisation of industrial excess heat; and the installation of the first district cooling system in the Baltics and Eastern Europe. This project is a good example of modernisation and expansion of medium to large DH systems and the simultaneous phase out of fossil fuels.

Estonia has a long history of DH, and about 70% of the heat demand is covered by DH in around 200 privately owned DH networks. The remainder is covered by individual heating solutions based to a large degree on biomass, followed by electricity and natural gas. In terms of DC, the country is a newcomer (Fernández, Roger-Lacan, Gährs, & Aumaitre, 2016).

This case study covers the DHC system of Tartu, the second largest city in Estonia with around 94,000 inhabitants; 1,938 buildings are connected to the DH network, which corresponds to around 70,000 end users. The modernisation of Tartu's DH system started in 1995, in response to the deteriorating air quality in the city caused by household wood and waste stoves. The low quality of the DH service led to customers disconnecting from the DH network (Fortum Tartu AS, 2017).

First, peat and wood chips were introduced as fuels to replace some of the natural gas and oil in the system (Fernández, Roger-Lacan, Gährs, & Aumaitre, 2016). Second, with a focus on sustainable development, the local authority developed the Tartu Master Plan in 1999, which included DH zoning. In the DH zones, new buildings and buildings undergoing major renovation have to connect to the DH network. The DH zones are updated every couple of years, aligning urban planning with the interests of the DH supplier (Fernández, Roger-Lacan, Gährs, & Aumaitre, 2016). In 2000, the system was privatised and is now owned and operated by AS Fortum Tartu. In 2006, Fortum began its own biomass and peat production, and started using these as fuels for a new CHP plant that started operation in 2009. Between 2009 and 2014, the system expanded, mainly by acquisition of an adjacent DH supply area (Tamme). As part of the restructuring, old fossil fuel boiler capacity in the city centre was closed in 2013 (Fernández, Roger-Lacan, Gährs, & Aumaitre, 2016). An overview of the main DHC production infrastructure in Tartu is given in Table 6.

In 2016, the first DC network in the Baltics and Eastern Europe was established in Tartu. The system produces 1.3 GWh/year of cooling for local customers with large cooling demands (the national museum, a shopping centre, and a hotel). The first DC system is based on free cooling from the local river and is partially integrated with the DH system—waste heat from the DC in the national museum is fed back into the DH grid using heat pumps. Moreover, since 2015, industrial waste heat from Kroonpress is integrated into the Tartu DH network (Fortum Tartu AS, 2017). In 2017, the second DC project (Aardla) servicing 17 buildings with a capacity of 5.4 MW and annual sales of 5.6 GWh was launched. The excess heat from this DC system is used in the DH system. Finally, smart DH meters have been installed at most customer points.

Between 2019 and 2021, low temperature DH (60ºC-65ºC) is tested in a residential area (Tarkoni) with 54 consumers, a total capacity of 4.3 MW, and a network length of 4.6 km. In 2020, a number of heat recovery projects are also being implemented in relation to the RELaTED project: industrial excess heat using heat pumps (food factory, printing company, ice arena) and heat recovery from warm condensate water from flue gas condensation at the CHP plant (RELaTED[1]).

Altogether, the above changes in the DHC system mean that the DH supply is running 80% on renewable energy resources and that the CO_2 emissions have decreased by more than 50% since 2008. Network length has doubled since 2008 and network losses have decreased by 50%, mainly due to the replacement of soviet era DH pipes with pre-insulated DH pipes. All in all, 77% of the current DHC network in Tartu has been constructed after 1999 (Fortum Tartu AS, 2017); (Külaots, 2020).

Financing and price structure

All production infrastructure owned by AS Fortum Tartu is also financed by the company's own equity and banks. Waste heat providers typically finance their own DH connections, but new business models are being discussed where the utility company (Fortum) finances the necessary company internal installations for waste heat utilisation (Külaots, 2020).

In 2020, the maximum chargeable DH price is €64.02/MWh (incl. VAT). The applied price is below that at €58.20 /MWh. It applies to all DH customers throughout the whole year. DC prices are agreed on a case-by-case basis between the DC supplier (Fortum) and the customer. Similar for waste heat utilisation, prices are negotiated between companies and the utility company (Fortum).

Table 6: Overview of main DHC production infrastructure in Tartu

Production units in the Tartu DH system	Year installed	Installed capacity/ production	Comments
CHP plant (Anne Soojus)	2009	50 MW_{th} 25 MW_{el}	Wood chips, peat
Flue gas condenser (Anne Soojus)	2009	15.7 MW_{th}	
Heat-only boiler (Anne)	1983	119 MW_{th}	2 boilers (2x21 MW), fired by wood chips and peat (since 1995) 2 natural gas boilers (2x38.5 MW)
Flue gas condenser (Anne)	2005	4.2 MW_{th}	Connected to the biomass boilers
Peak load / backup boilers (Ropka)	2014	76 MW_{th}	2 natural gas-fired boilers
Heat-only boiler (Turu 56)	1996	4 MW_{th}	Oil boiler, reserve boiler for prison
Heat-only boiler (Aardla 113)	2013	7 MW_{th}	1 boiler, wood chips and natural gas
Flue gas condenser (Aardla 113)	2013	2 MW_{th}	
Heat-only boiler (Tulbi 12)	2013	30 MW_{th}	2 boilers, natural gas
Heat-only boiler (Vaksali 51)	2013	17.4 MW_{th}	5 boilers, natural gas
District cooling (Tartu downtown)	2016	8.4 MW	2 chillers cooled by river water 1 heat pump using free cooling from river water Solar panels for own electricity consumption
Aardla district cooling	2017	5.4 MW	2 chillers cooled using a cooling tower 1 heat pump

[1] Magnus Raud: RELaTED: Low temperature (LT) heating project in Tartu. Fortum Tartu AS. Horizon 2020 grant agreement number 768567.

5.2.3 Policy framework and support programs

The DH sector is regulated at the national level, mainly through national energy strategies and the District Heating Act. The regulatory authority is the Estonian Competition Authority (ECA). The Estonian government has the goal of an 80% renewable energy share in DH in 2030, compared to 33% in 2011 (Republic, 2017).

Energy efficiency in DH networks is promoted at the national level as well. According to the National Energy Strategy from 2017, Estonia foresees a reduction of the fuel demand for heating by 40% in 2050. Due to ongoing renovations in the building stock, DH sales volumes are already expected to decrease by 30% in 2030 (Republic, 2017). In particular, the ECA enforces energy efficiency measures in the DH sector through requirements on decreased net losses or improved fuel efficiency in DH production (Fernández, Roger-Lacan, Gährs, & Aumaitre, 2016). Moreover, co-generation of electricity and DH is supported and expected to increase towards 2030 (Government of the Republic 2017).

DH consumer prices are regulated by the District Heating Act (Riigikogu, 2017) and approved and monitored by the ECA. DH price regulation consists of several elements:

- A maximum DH price, which is calculated by each DH supplier and reported to and approved by the ECA. The calculation of the price must take a number of economic, quality, and environmental requirements into account.
- The maximum DH price allows for a profit margin (justified profitability) for the DH operator, for which the ECA continuously updates calculation parameters. It is the product of: Regulated Assets Base (RAB) x Weighted Average Cost of Capital.
- DH prices can consist of both a fixed and a variable component.

In accordance with the District Heating Act, local authorities can determine "district heating regions" (DH zones) in comprehensive plans. In these DH zones, connection to the DH network is mandatory, but additional heat supply from other renewable energy sources is allowed. Development of new urban districts is typically subject to DH zoning.

CHP plants are supported for a duration of 12 years with premium tariffs on top of the electricity market price. This system will be phased out during 2021 (Külaots, 2020).

5.2.4 Ownership, process, and stakeholder involvement

The DHC system is owned and operated by AS Fortum Tartu, which is subdivided into three companies for DHC production, network and customer services, and local fuels production and procurement. Comprehensive city planning and DH zoning is carried out by the municipality of Tartu. The DHC sector is part of the Tartu's sustainable development plan. The City and AS Fortum collaborate in the DH zoning process.

AS Fortum Tartu cooperates with local businesses regarding industrial excess heat (Kroonpress) and supply of DC. The number of customers and the associated DH demand has been increasing steadily since 2000: the connected capacity and the number of customers have more than doubled (Fortum Tartu AS, 2017); (Külaots, 2020).

5.2.5 Impact and Co-benefits

Table 7 gives an overview of the indicators that have been analysed and results from the case. The table is a comparison of the following project-specific data and national average data per indicator:

Table 7: Benchmarking against national average

Indicator	Case study	National average	Comment
DH customer price	€58.2/MWh	€69.96/MWh*	Including VAT *National average, according to (Külaots, 2020)
Price of standard fuel for heating	€79-€131/MWh	€79-€131 /MWh	Heat pump/natural gas (lowest), wood stove (highest) (Külaots, 2020)
Share of renewable energy in heat generation	80%	36.5% biomass* 5.4% peat* 3.2% other*	* (Veske, 2018)
CO_2 emission factor (heating sector)	131 kg/MWh*	131 kg/MWh**	* (Fortum Tartu AS, 2017) ** (Latõšov, 2021)
Emissions savings compared to BAU	52%*	43%**	*Tartu: 2008-2019 (Fortum Tartu AS, 2017) **Estonia: 2011-2019 (Latõšov, 2021)
Heat losses in network	2008: 15.2%* 2016: 10.8%*	2018: 14%**	* (Fortum Tartu AS, 2017) (Külaots, 2020)
Temperature levels in network	105/55°C (winter) 75/48°C (summer)	From 140/70°C to 70/50°C	(Külaots, 2020)
Network size	194 km (DH) 6 km (DC)	1,450 km	Total trench length (2013), (Reidla, 2017)

Co-benefits

From the perspective of Fortum Tartu AS (Külaots, 2020) several co-benefits are reported. First, the excess heat from CHP production can be utilized in the district heating system, which improves the efficiency of the CHP operation and avoids investments in other heat production units. The ongoing diversification of the production portfolio also makes it possible to link more heat sources to the network, such as industrial excess heat and excess heat from the district cooling system. With the first low temperature district heating areas being implemented the potential for excess heat integration is increasing further. This will also allow and necessitate diffusion of demand side response and heat/cold storage solutions in the near future.

5.2.6 Success factors and barriers

The reported key barriers and challenges are:

- Energy efficiency: one of the key barriers is that the District Heating Act and tariff regulation do not promote efficiency investments in the district heating system: while the calculated maximum district heating price seeks to safeguard a justified profit for the operator and reasonably fair consumer prices, it does not specifically promote energy efficiency and lower district heating consumption, as production units are likely to operate at just below the maximum allowable price.

- Price calculation: the RAB is based on historical costs, and therefore is somewhat inflexible for operators that want to carry out investments in renewable energy and energy efficiency.
- Validation of new unproven technologies: from the perspective of the local supplier, there is substantial risk in investing in unproven technologies. There is in some cases a challenge in phasing in new technologies, while maintaining a good business case.
- Communication of the planned change: even though continuous efforts are being made in communicating the transition of the district heating system to the public, reaching the majority of customers remains a challenge.

The analysis of the case study revealed the following key success factors:

- Competitive price level: the district heating price in Tartu is below the national average and at a level where it can compete with alternative heating solutions, such as biomass boilers and individual heat pumps.
- Strong vision: from the perspective of Fortum Tartu AS, the focus on clean and affordable district heating creates a strong vision for the Tartu district heating system, making the service popular with the majority of the citizens.
- Consistent and continuous communication about advantages of district heating: the local supplier actively engages with (new) consumers and other stakeholders regarding the comparably high comfort and affordability of district heating
- Engaged and devoted employees: concerning Fortum Tartu AS, this is important as it, for instance, directly relates to the customer service in the district heating system.
- Support from local authorities: the city of Tartu and Fortum Tartu AS share similar visions and collaborate on various projects under the “Sustainable Tartu” umbrella, including the SmartEnCity and RELaTED projects.

5.3 Espoo Clean Heat, Finland

5.3.1 Project context

Table 8: Key figures of the project.

Funding (share %)	Total investment (total)	MW installed	km network	Temperature levels	Energy generated	Network loss	Supply source	Energy (MWh) / (%)	CO_2 (tCO_2) / (%)	DH share in the market	Customers connected	Customer price (€/MWh)
100% private capital (Fortum, Banks)	N/A	238	900	75-110°C (supply) 38-50°C (return)	2,037 GWh	10%	2018: Coal: 1,862 GWh Gas: 917 GWh Bio: 190 GWh Electricity: 100 GWh Oil: 8 GWh		29% [projected, 2014-2020]	89%	250,000	

Source: (Kuusela, 2019 & 2020) (Luomala, 2020) (Keskivali, 2020)

5.3.2 Project summary

The case study covers the first phase of the Espoo Clean Heat initiative, which aims to achieve a carbon-neutral DH system by 2030 in Espoo. During this phase (until around 2022), an almost 100% dependence on coal and other fossil fuels is being turned into 40% carbon neutrality based on a combination of different technologies and fuels. These include biomass, geothermal, large heat pumps, excess heat, and two-way DH and DC. This case is a good example of a local supplier-municipality collaboration around a common green vision and the diversification of the DH supply with modern technologies and local resources.

This project is the case of a large DH system undergoing a complete decarbonisation of heat sources within a relatively short time span of 16 years (2014-2030). The focus of the case study is the period between 2014 and 2022, during which the Espoo DH system is developing from close to 0% carbon neutrality and a heavy dependence on coal to 40% carbon neutrality in 2020 and 50% in 2022. Since 2014, Espoo has replaced 25% of its coal- and natural gas-based heat production with a combination of biomass pellet boilers, heat pumps (based on wastewater and excess heat from small data centres), and a large heat accumulator to optimise the operation of the DH system (see Table 9).

In 2020, one coal unit was decommissioned (80 MW_{th} at the Suomenoja CHP plant) and a new bio-heating facility was commissioned, increasing the share of carbon-neutral heat production to 40%. The biomass used in the boilers is mainly based on domestic forestry residues. Apart from that, thermal storage and demand-side management are used to manage peak demand, optimise DH production, and integrate electricity from renewables (through large heat pumps). A geothermal plant is scheduled to open in 2021 and later in the year, a third heat pump will be installed to capture more excess heat from purified wastewater. Additionally, in 2016, DC based on 30 MW heat pumps was implemented. Decarbonisation of the production will be further supported by comprehensive end-to-end digitalisation of supply and demand forecasting, DH network modelling and predictions, heat production, and network operations and maintenance.

Financing and price structure

Detailed investment figures are not publicly available. All investments were carried out by means of private capital and bank loans available to Fortum and the collaborating partners.

Table 9: Overview over main production infrastructure in Espoo

Projects implemented between 2014 and 2022	Year installed	Installed capacity/ production	Comments
Heat pump 1 (Suomenoja)	2015/2016	30 MW_{th}	2 heat pumps supplying DH and DC (around 15 MW_{th}) Heat source: wastewater
Biopellet conversion plant (Kivenlahti)	2016	80 MW_{th}	Replacing a heavy fuel oil heat-only boiler
Excess heat	2016	N/A	3 data centres and 1 hospital are connected (Two-way DH)
Biogas from landfill	2015-2016	12 GWh/year	
Demand-side management	2019	15-20 MW	Some customers are contracted with interruptible DH supply to allow for peak shaving

Projects implemented between 2014 and 2022	Year installed	Installed capacity/ production	Comments
Biomass boiler (Kivenlahti)	2020	58 MW_{th}	49 MW_{th} boiler plus flue gas condenser Fuel: mainly forestry residues
Geothermal plant (Otaniemi)	2021	20-40 MW_{th}	World’s deepest geothermal plant (6.4 km) Partner company: St1
Heat accumulator (Suomenoja)	2015	800 MWh	For optimisation of heat pump operation
Heat pump 2 (Suomenoja)	2021	20 MW_{th}	Heat source: wastewater and seawater

5.3.3 Policy framework and support programs

The overall investment strategy within the Espoo Clean Heat initiative is driven by EU Emissions Trading System (ETS) scheme, the national Finnish goal to phase out coal by 2029, and the Finnish taxation of fossil fuels. Espoo Clean Heat is a close cooperation between the City of Espoo and Fortum. Projects are usually financed using Fortum’s own equity.

The Finnish DH sector is less regulated than, for instance, the DH sector in other Nordic countries. Finland has no distinct District Heating Act and no direct price regulation, nonprofit regulation, or other regulation (e.g. mandatory connection to the DH network). DH suppliers compete with individual heating solutions on market terms. However, the Finnish Competition Authority has determined that DH operators are in a “dominant market position” with the consequence that rules regarding prohibitive prices and price discrimination apply; pricing should happen on equal terms for all customers and the Competition Authority may investigate if unreasonably high prices are suspected (Patronen, Kaura, & Torvestad, 2017). DH consumers can disconnect from the DH network if cheaper individual heating solutions can be found. In Espoo, there is already some competition from building-specific heat pumps, and some customers are leaving the network. DH projects undergo standard permitting procedures at the local authority.

5.3.4 Ownership, process, and stakeholder involvement

Besides being a strategic collaboration between the City of Espoo and Fortum, Espoo Clean Heat also includes a number of partner companies at the different production facilities; 250,000 out of the 280,000 inhabitants of Espoo are connected to the DH network (89%).

Fortum and the City of Espoo began formulating Espoo Clean Heat in 2016 to give an identity and image to the transformation of the DH system and to make the project easier to communicate to the public. Fortum could see that the upcoming projects were quite visible and had to be implemented within short timeframes, which is why the communication strategy was intensified. For instance, intermediate targets and a roadmap with initiatives were developed as a general overview for the public. The DH strategy and its projects were also communicated using social and traditional media, including videos, presentations, etc.

Fortum uses customer campaigns to target certain groups—for instance, in relation to demand-side response and management. There has been some communication effort to increase the awareness of the public on the benefits of the Espoo Clean Heat strategy for the whole energy system (for example, by highlighting large heat pumps that enhance sector integration) (Luomala, 2020).

Fortum collaborates with Helsinki Region Environmental Services Authority HSY (use of excess heat from treated wastewater in heat pumps). There is also a collaboration between Fortum and the City of Espoo regarding the zoning of new large data centres (100 MW) in relation to the DH network and electricity supply. In terms of excess heat delivery, Fortum has entered collaborations on two-way DH with some small data centres and one hospital. There is a monthly district heat price list available for these industrial partners (Luomala, 2020).

5.3.5 Impact and Co-benefits

Table 10 gives an overview of the indicators that have been analysed and the results from the case. The table compares the following project-specific data and national average data per indicator:

Table 10: Benchmarking against national average

Indicator	Case study	National average	Comment
DH price	€95.97/MWh	€94.84/MWh*	*Arithmetic mean (national average) (Luomala, 2020)
Price of standard fuel for heating	c€9.6/kWh (DH price from above)	c€8.5-11.0/kWh*	*Direct electricity (Keskivali, 2020)
Share of renewable energy in heat generation	2020: 40% 2022: 50%* 2026: 85%* 2029: 95%*	2015: 16% direct renewables 73.5% co-generation (including 23.3% renewables)**	*Projected share ** (Kohopää & Tiitinen, 2017)
CO_2 emission factor (heating sector)	213 g/kWh (2019)	148 g/kWh (2017-2020)*	*In co-generation (Federly, 2021)
Emissions savings compared to BAU	40%* (share of renewable energy in heat generation)	37%** (2009-2019)	*2014-2020 (Espoo) **2009-2019 (Finnish Energy, 2020)
Reduction (potential) of heat losses in network	2010: losses 8.1% 2018: losses 7.9%	2010: losses 9.5%* 2018: losses 11.5%**	* (Finnish Energy, 2011) ** (Finnish Energy, 2019)
Temperature levels in network	75-110°C (supply) 38-50°C (return)	65-115°C* 40-60°C*	* (Hillamo, u.d.)
Typical size of network	900 km	14,610 km*	* Total trench length (one way) (2015) (Kohopää & Tiitinen, 2017)

Co-benefits

The main co-benefit is that through the diversification of the heat supply, a larger variety of low-cost heat sources are now integrated into the district heating system. This includes excess heat from data centers and wastewater treatment. This integration does not only lower the consumption of fossil fuels in the system, but also helps improve the energy efficiency and business case of the industrial partners supplying the excess heat.

5.3.6 Success factors and barriers

The identified key barriers and challenges are:

- Combining production portfolio changes with urban planning: diversifying the heat supply and using more local heat sources, also means that district heating is becoming more “visible” around the city. Making sure that district heating units are optimally integrated into the urban space is thus a challenge.
- Sustainable business case: reducing emissions while ensuring sustainable business fundamentals is challenge for a company like Fortum.
- Validation of new unproven technologies: from the perspective of the local supplier, there is substantial risk in investing in unproven technologies. There is in some cases a challenge in phasing in new technologies, while maintaining a good business case. In the case of Espoo this concerns, for instance, the geothermal plant.
- Zoning and permitting: in relation to the new spatial planning challenges arising from a more local district heating supply, urban zoning and permitting processes can sometimes delay the project schedule, which can be a challenge for the local supplier and its partners.
- Communication of the planned change: even though continuous efforts are being made in communicating the transition of the district heating system to the public, reaching the majority of customers remains a challenge.

The analysis of the case study revealed the following key success factors:

- Vision and communication: the Espoo Clean Heat initiative represents a strong and unrelentless vision and clear roadmap, and the progress with implementing both is being communicated consistently and continuously. Also, both, the city of Espoo and Fortum use various communication channels and media to ensure as many citizens as possible can engage with Espoo Clean Heat.
- Engaged and devoted employees: similar to the case of Tartu, this mainly concerns the employees of Fortum, who with the Espoo Clean Heat initiative, are working towards a long-term common goal.
- Support from local authorities: this has been essential in making Espoo Clean Heat a reality, as it is a shared vision between the city and Fortum. The city also supports the efforts within district heating through spatial planning, e.g. by siting large data centers where their excess heat can easily be utilized for district heating.
- National targets: Finlands’ climate and energy targets have been important for shaping the business direction of Fortum towards more investments in renewable energy.

5.4 Mórahalom Cascading Geothermal DH system, Hungary

The information for this case study has been compiled in collaboration with Gabor Heves, IMRO-DDKK Nonprofit Ltd. Hungary (Heves, 2019 & 2020).

5.4.1 Project context

Table 11: Key figures of the project

Funding (share %)	Total investment (total)	MW installed	km network	Temper-ature levels	Energy generated (MWh)	Network loss	Supply source	Energy (MWh)	CO_2 (tCO_2) (%)	DH share	Customers connected	Customer price (€/MWh)
€850,000 (~50%) from KEHOP and the GEOCOM project (EU Concerto, FP7)	€1.87 million	1.5 MW (geothermal heat) 80 kW_{el} / 126 kW_{th} (in 2 CHP units) 418 kW_{th} (heat pump) 121 m^2 solar collectors	3 km	62.1°C (geothermal water) 90-120 °C (from CHP engines)	Heat: 5,194 MWh (18,700 GJ) Power: Around 500 MWh per year	8.69%	80% geothermal energy 10% natural gas (grid) The remainder is geothermal CH_4	1,320	866t/ year 70% (total system)	54% (of public buildings)	12	N/A DH produced for own consumption in public buildings

5.4.2 Project summary

The project covers the cascading geothermal DH system in Mórahalom, which is a small-scale system supplying heat to the local public buildings and a spa. The system integrates geothermal heat with CHP units and a heat storage to make optimal use of the geothermal energy in the area. The project also included building retrofits to further optimise the heat consumption and efficiency of the whole supply system. The Mórahalom geothermal energy system is a good example of integrating renewable DH with building energy efficiency, low temperature DH, and local development, saving the municipality substantial amounts of natural gas expenditures, among others.

DH traditionally supplies about 15% of the housing stock in Hungary, to around 650,000 customers, which has been slightly increasing since 2013 (Hungarian Energy and Public Utility Regulatory, 2018). Altogether 58% of buildings are heated by natural gas, 12% by biomass, 11% by district heat, 8% by electricity, 6% by coal, and 5% by other sources (Heat Roadmap Europe, 2017).

The case is located in Mórahalom, a small town in the south of Hungary with a population of around 5,800 inhabitants. The geological conditions in the area, belonging to the Pannonian geothermal region, are excellent for geothermal water production. The timespan covered is 2008-2014. In 2008, the establishment of a geothermal DH system started as a major part of a local development strategy, which significantly boosted local development in the town (Pári, Gábor, & Ömer, 2015). The DH system replaced the existing natural gas supply in 12 municipality-owned public buildings. It consists of two geothermal systems: one for heating the public buildings and one solely for supplying hot thermal water to the local spa (Pári, Gábor, & Ömer, 2015). The DH system supplies around 5,200 MWh of heat annually. It is a cascading geothermal system with an abstraction well (depth: 1,270 m) and an injection well (depth 900 m), in which the used DH water is recirculated into the deep geothermal reservoir.

Because of the high methane content (87%) of the geothermal water in Mórahalom, a gas separator and small CHP units were installed, which make it possible to remove the methane and convert it to electricity and heat in an automated process. The CHP units are equipped with a flue gas condenser, and the produced electricity is used to run the system and to cover electricity consumption in the public buildings (Pári, Gábor, & Ömer, 2015). The hot water from the CHP units is injected into the geothermal DH system. In the second phase of the project, the system was upgraded with a 418 kW_{th} heat pump and thermal storage tank, which uses the DH return water (40ºC) as a heat source to produce more hot water and re-inject it into the heat supply at the building level (end of DH loop). In this way, some newly constructed buildings can also be heated by the geothermal DH system (Pári, Gábor, & Ömer, 2015).

As additional measures, a number of the public buildings had to be retrofitted to make them compatible with geothermal DH temperatures. This involved standard energy upgrades of windows, doors, and building envelopes (thermal insulation). To make use of the good solar conditions in this region of Hungary, solar collectors were installed on some of the buildings as well (Pári, Gábor, & Ömer, 2015).

With the new geothermal DH system, the share of renewable energy has gone from 0% to more than 80%, while offsetting 540,000 m^3 of natural gas annually (Pári, Gábor, & Ömer, 2015). Compared to the previous system based on natural gas, about €140,000 can be saved annually.

Financing and price structure

The system is owned and operated by the municipality of Mórahalom. Only public buildings are connected to the DH system.

The municipality has had a strong focus on external project funding at the national and EU levels over the past 20 years. The Interreg Europe programme provided funds to design the geothermal system. Building the DH system was supported by the national EEOP programme, which provided roughly 50% of the needed funding. A smaller contribution came from the EU Concerto programme and from the EEA/Norway grants programme. Co-funding was provided from the core budget of the municipality.

The municipality produces the geothermal DH for its own consumption in the public buildings.

5.4.3 Policy framework and support programs

At the time of project implementation (Phase 2), Hungary's Renewable Energy Action Plan (NREAP) promoted a doubling of the renewable energy share to 14.65% in 2020 and specifically addressed the use of geothermal energy in this regard (Deputy Secretariat of State for Green Economy Development and Climate Policy , 2010). In the 2019 edition of the National Energy Strategy, a greenhouse gas (GHG) emissions reduction of 40% by 2030 compared 1990 levels was included (Ministry of Innovation and Technology, 2019). The share of natural gas in DH is to be reduced to 50% compared to the 2010 level of 83% (Nagy, 2019). In the original NREAP, a national building energy efficiency programme was announced after 2011.

The DH sector is regulated at the national level (Act XVIII of 2005 on DH). The sector is monitored by the Hungarian Energy and Public Utility Regulatory Authority. According to a ministerial decree from 2006, new buildings larger than 1,000 m^2 were to be assessed in terms of a possible connection to DH, block heating, or supply by renewable energy sources. For the 2009-2010 period, the Environment and Energy Operation Programmes (EEOP)[2] promoted investments in green energy and energy efficiency, including an EEOP called "Energy modernization of the district heating sector" (EEOP-2009-5.4.0) (Deputy Secretariat of State for Green Economy Development and Climate Policy , 2010). From the case study's point of view, this was the single most important policy programme, because it covered 50% of the investment costs (using EU Structural Funds as well as national co-funding), so it was the only national programme providing direct support.

The Green Investment Scheme offered funding for energy efficient modernisation of the building stock. Geothermal energy production was expected to more than triple by 2020 (Deputy Secretariat of State for Green Economy Development and Climate Policy , 2010).

Since January 2020, DH providers are required to provide data for the Lechner Knowledge Centre. The aim of creating this public database is to provide the necessary background information for energy auditors, so that they can include the DH primary energy conversion ratio and the share of renewable energy in their calculation (Nekünk.

DH zoning is not mentioned in Act XVIII of 2005 on DH or in the Government Decree 157/2005, which regulates the implementation of this act. DH prices are state regulated. Due

[2] KEHOP is the Hungarian acronym

to political and social reasons, market-based prices have been reduced by 25% since 2012. (This also applies to residential electricity and gas prices.)

Due to the low price of natural gas, DH is less economically advantageous than using natural gas. Therefore, to prevent further consumers detaching from the system, a government decree has forbidden consumers to leave the DH grid.

In an attempt to protect consumers, a number of measures (most importantly, reduced utility bills) have resulted in reducing residential utility debts by 54% and reducing the number of consumers disconnected from power services by 57% (Heves, 2019 & 2020).

5.4.4 Ownership, process, and stakeholder-involvement

The geothermal DH system is owned and operated by the municipality. It is the result of a high municipal commitment to sustainable economic and environmental development. The system was designed by a private consultant company and implemented by the municipality of Mórahalom and its own institutions.

5.4.5 Impact and Co-benefits

Table 12 gives an overview of the indicators that have been analysed and of the results. The table allows a comparison of the following project-specific data and national average data per indicator:

Table 12: Benchmarking against national average

Indicator	Case study	National average	Comment
DH price	N/A*	€50.6/MWh**	*Case study: DH produced for own consumption in public buildings ** (Kasza, 2017) excl. VAT (5%)
Price of standard fuel for heating	3.1 ct/kWh	3.1 ct/kWh	(Eurostat, 2021) (Heves, 2019 & 2020)
Share of renewable heat in heat generation	90%*	16.5%**	* Geothermal ** Including surplus heat and renewables used for co-generation
CO_2 emission factor (heating sector)	0.422 g/kWh*	344 g/kWh	*Due to estimated methane emissions from the geothermal well (Heves, 2019 & 2020)
Emissions savings compared to BAU	70%	10-40%*	*Theoretical potential is up to 85% (Heves, 2019 & 2020)
Reduction (potential) of heat losses in network	N/A (new network)	Average (2018): 12.6%*	* (Hungarian Energy and Public Utility Regulatory, 2018) National programme to upgrade old DH grid network (The Ministry of Innovation and Technology and the Hungarian Energy and Public Utility Regulatory Authority)
Temperature levels in network	63°C	Up to 110°C in winter Average 60°C in summer (hot water)*	*Standards define three heat levels. The medium is given here. Daily variations can be ca. 3-5°C. Seasonal variations can be higher. (Heves, 2019 & 2020)

Indicator	Case study	National average	Comment
Typical size of network	3 km	Total grid length: 1,951 km in 171 DH systems*	*650,000 homes are heated by DH = 15% of all homes. 12% of DH is used by public institutions, 25% by industry. (Heves, 2019 & 2020)

Co-benefits

The main co-benefits identified in the case was that the geothermal project has improved the local competitiveness by substantially reducing the municipality's heat expenses. In this way, funds were unlocked for further investments in renewable energy and energy efficiency. Due to the very low operational costs of the system, staff costs are also kept low. However, this also implies that attention needs to be paid to maintaining operational know-how of the geothermal system. Finally, through participation in various funding programs and European research projects, the municipality gained access to a wider knowledge and expert networks.

5.4.6 Success factors and barriers

The identified key challenges are the following:

- Size of the municipality: Being a small municipality, human resources are limited in Mórahalom. This means that skilled personnel to operate and maintain the heating system is scarce.
- Monitoring and evaluation: As a result of the lack of skilled personnel no actual monitoring and evaluation of the implemented measures has been maintained. It is therefore difficult to ensure continuous improvement and learning from the project.
- Financing the initial investment: Due to the small budget of the municipality there is limited capital for investments. In the case of the geothermal heating system, this challenge could be turned into a success factor by getting access to third party funding from various sources.

The key success factors identified in the case included:

- Municipal commitment: A committed municipal leadership that amongst others supported the search for funding of the project and the integration of building energy efficiency into the project.
- High share of third-party funding (national and European): This made it possible to cover some of the investment costs related to the new technical components of the system.
- Low maintenance system: This ensures the continued operation of the system in spite of lack of human resources in the municipality.
- Local income: The income gained from local economic development (most importantly, from increasing incomes from local spa) helped improve project economy.

5.5 Waste heat from data centre, Ireland

5.5.1 Project context

Key figures of the project

Table 13: Key figures of the project

Funding (share %)	Total investment (million total)	MW installed	km network	Temper-ature levels (°C)	Energy generated (MWh)	Network loss	Supply source (MWh)	Energy (MWh) / (%)	CO_2 (tCO_2) / (%)	DH share in the market	Customers connected	Customer price (€/MWh)
Government: 57% EU: 5% Municipality (ESCO): 38%	8.0	3 HP 3 el. backup	~ 2	85/55 Winter, 75/45 Summer	6,890	7.5%	4,751 waste heat 2152 elec.	5,000 /	1,000 / 59%	0%	1,400 (first phase)	55 (bulk price)*

* Bulk refers to selling heat to the building facility manager (at the building heating substation). The latest estimates for price are €55/MWh for commercial customers, €60 for residential customers, and €70 for the council buildings.

(Gartland & O'Shea, 2019 & 2020)

5.5.2 Project summary

This case study presents the project in Tallaght town centre (South Dublin municipality) where the share of DH is currently 0% and more than 90% residential buildings use individual gas boilers for heating purposes. The project timeline is Q4 2019-Q1 2021. It is a pilot project that received governmental funding to prove the concept of DH in Ireland. The project is representative of any situation with new data centres near areas where waste heat can be used for heating purposes in buildings. The data input was provided from member of CODEMA, energy efficiency agency of Dublin (Gartland & O'Shea, 2019 & 2020).

Ireland has no history of large-scale DH implementation and only few small-scale examples of DH projects (communal DH schemes). More than 99% of buildings are individually heated, with the vast majority using gas and oil as the main heating fuel.

The case study investigates the first DH scheme in Dublin, a first for a not-for-profit municipal utility in Ireland with lots of challenges and learning. The heat will be supplied from waste heat from a data centre extension coupled with heat pumps. The data centre was mandated to provide the waste heat to a local DH scheme operated by the municipality when one became available through their planning permission. Working with data centre waste heat brought contractual and legal challenges to overcome. Heat was to be provided for free.

The existing buildings that will be supplied by the new DH network are being serviced by gas boilers (60%-85% efficiency, where 60% refers to old non-condensing gas boilers and efficiency being calculated with the higher heating value (HHV)). In contrast, in other European countries that would correspond to about 67% efficiency using lower heating values (LHV) and consist of municipality offices and a college. There is also a new residential development in the area (apartment blocks). These new dwellings would most likely install individual air source heat pumps if not connecting to the DH network. This network has the potential to grow to include other new and existing developments, which includes both residential and commercial.

In Phase 1, different customers are connected: public buildings (South Dublin County Council civil offices, library, school, and new innovation centre), an existing college campus (Technological University Dublin – Tallaght), and a residential development (1,400 new apartments).

Financing and price structure

In phase 1 the total CAPEX is €7,972,000. This includes the energy centre building and civils, heating plant and auxiliary equipment, the heat network and civil works, design work, and customer substations. The cost per MWh of heat produced is €1,157/MWh and the cost per installed primary heating capacity (HP heating capacity excluding backup boilers) is €2,657,333/MW. The internal rate of return (IRR) is 5% over a 25-year timeframe.

Capital costs include the energy centre building and civils, heating plant and auxiliary equipment, the heat network and civils work, design work, customer substations. The ESCO's capital costs are recouped through a fixed monthly payment from SDDH, and SDDH capital costs are recouped through the heat sales price to the customer.

Operational costs include maintenance, fuel, and repair costs. There is both a fixed and variable element of the operations and maintenance. The variable relates to the operations and maintenance costs incurred due to the supply of heat. Fixed operations and maintenance relate to the costs incurred regardless of the quantity of heat supplied.

Design, build, operate, maintain local heat supply contract with the ESCO is a fixed heat supply price over a 10-year contract. The tariff structure has not been finalised but should be either the same or a lower price than the counterfactual, which is gas boilers, and is likely to vary by customer type (residential/commercial) and consumption. It is also likely to include a motivation tariff where price will be adjusted based on °C above (price increase) or below (price decrease) the agreed return temperature.

There is no obligation for customers to connect, and there are no multi-customer DH networks operating in Ireland. The bulk supply price average is estimated at €60/MWh for residential and €55/MWh for commercial.

(Gartland & O'Shea, 2019 & 2020)

5.5.3 Policy framework and support programs

Regulation of the DH sector

There was no regulatory framework for DH in Ireland, but a consultation was ongoing (December 2019-February 2020) by the national Department of Communications, Climate Action & Environment. This consultation informed a future regulatory framework at the national level for DH in 2020 which was being reviewed on 28 May 2021 (Department of the Environment, 2020). There are also no specific policies for DH as a technology, but other policies support DH rollout; these policies include the national-level building regulations, which apply to all new dwellings and non-dwellings and require low carbon heating and renewable energy supply.

Support and funding programmes: local, national, regional

The national Climate Action fund of €500 million was first launched last year, and 2 DH projects were granted funding in the first year with a total of €25 million. The Tallaght District Heating System received €4.5 million in this call as a pilot project to prove the concept of DH in Ireland.

The project received further support from the Interreg Europe funding (project HeatNet), €400,000, and the municipality funded through an energy service company (ESCO) financing over a 10-year contract to equal €3.0 million.

5.5.4 Ownership, process, and stakeholder involvement

Codema and the South Dublin County Council (SDCC) initiated and are the driving stakeholders behind the project. SDCC is the project lead and was the policymaker, creating planning policies that helped facilitate this project.

The DH network will be owned by the South Dublin District Heating Company (SDDH). This is the first not-for-profit public utility in the country. The design, build, operation, and maintenance of the network will be carried out by the ESCO. After 10 years, SDDH has the option to take over operation itself or appoint the ESCO.

The institutions and actors involved in the Tallaght Scheme are as follows:

- Codema – Dublin Energy Agency (Technical, policy, funding, contracting, and procurement leads)
- SDCC (project owner, planning, and legal lead)
- External technical and legal advisors

- Local data centre (heat supplier, heat supply for free)
- Local developers and existing building owners (heat customers)
- Department of Climate Action (grant funder)
- ESCO (responsible for the final design, build, operation, and maintenance)

The main risk for the ESCO is that the system it builds does not achieve the efficiency used to calculate the price at which SDDH will buy the heat.

The responsibilities of the ESCO are to provide some upfront capital, which is paid back by SDDH through a monthly payment. Other responsibilities include maintaining water quality in the data centre waste heat recovery loop, responding to failures, maintaining a good level of service, providing high level specs and guidance for new connection customers (M&E designers), producing heat with a low carbon content and high renewable energy content, providing heat at the price tendered (subject to certain indexing and waste heat unavailability), metering heat demand and efficiencies, and sharing this information with SDDH.

South Dublin planning policies played an important role in the development of the project, specifically policy 5 and policy 6, which refer to waste heat and DH, respectively. Planning conditions for development of the data centre include the provision of waste heat recovery infrastructure for delivery to the boundary of the site and submission of a report outlining waste heat availability. To be granted planning permission, development proposals for new industrial and commercial developments and large extensions to existing premises where the processes associated with the primary operation of the proposal generates significant waste heat must:

- Carry out an energy analysis of the proposed development and identify the details of potential waste heat generated and suitability for waste heat recovery and utilisation onsite and with adjoining sites; include heat recovery and reuse technology onsite; and include heat distribution infrastructure above or below ground (including future-proofing the building fabric to facilitate future connection, safeguarding any pipe work routes up to the boundary to adjoining sites)

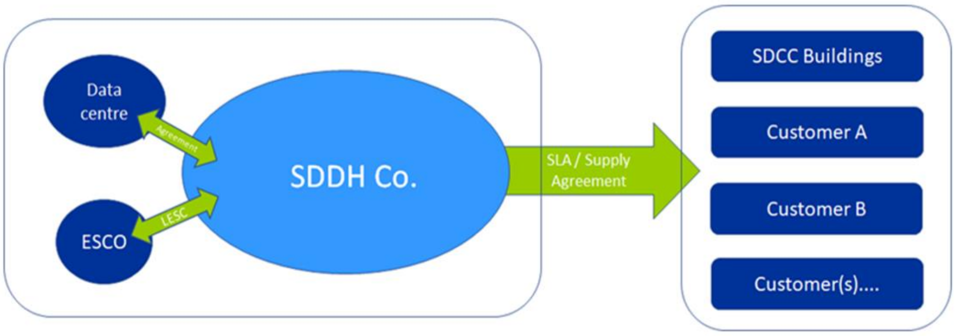
or

- Provide evidence that heat recovery and distribution has been fully explored and is unfeasible.

The contract will be a local energy supply contract (LESC), meaning a contract between SDDH and the ESCO for the design, construction, and installation of energy equipment (the works) and supply of energy through a DH network (services and supply).

Under an LESC, SDDH will buy the heat produced from the ESCO for a defined price (and customers pay SDDH). How this heat is produced, and the risks associated with this production is the responsibility of the ESCO. Figure 4 shows the contract and agreements structure.

Figure 4: Contract and agreements structure



(Gartland & O'Shea, 2019 & 2020)

5.5.5 Impact and Co-benefits

Baseline

Ireland has no history of large-scale DH implementation and only few small-scale examples of DH projects (communal DH schemes). More than 99% of buildings are individually heated, with the vast majority using gas and oil as the main heating fuel. Compared to the standard situation, the project increases the share of renewables. The standard situation without the project would be that all existing buildings in the project area would be heated with gas boilers (efficiency of 60%-85%) and new buildings would be connected to air source heat pumps (Gartland & O'Shea, 2019 & 2020).

Policy

The project developed an evidence-based, local-level energy planning policy for 6 years. A national-level policy framework for DH is just now being developed. This project received government funding as a pilot project to prove the concept of DH in Ireland.

Market

There is almost no existing DH market of DH.

Table 14 gives an overview of the indicators that have been analysed and of the results. The table allows a comparison of the following project-specific data and national average data per indicator:

- Share of waste heat
- CO_2 factor
- DH heat price
- Heat price (e.g. gas)
- Temperature level (delta)
- Length of network

Table 14: Benchmarking against national average

Indicator	Case study	National average	Comment
DH price	5.5-7.0 cents/kWh (varies depending on customer type)	Unknown	National averages are based on the counterfactual (gas boilers) because information not available for DH networks.
Price of standard fuel for heating (gas in Ireland)	Gas is N/A	6.5 cent/kWh (excluding VAT)	Residential gas price is based on small residential consumers. As the DH network is electrically fuelled, a direct comparison on fuel is not relevant. A comparison on heat price shows DH is approximately 6 cents/kWh and individual gas boiler heat is 8.1 cents/kWh for small residential customers.
Share of renewables in heat generation	99% (heat pumps)	6.5%	The national average is predominantly biomass but also includes heat pumps and solar thermal.
CO_2 emission factor (heating sector)	101 kgCO_2/MWh heat	256 kgCO2/MWh	National average assumes heat produced from 80% efficient individual building gas boilers; this is the most prevalent heating source in cities where DH infrastructure would be installed as an alternative.
Emissions savings compared to BAU	59%	N/A	
Temperature levels in network	85/55 °C Winter 70/50 °C Summer		
Typical size of network	1.6 km	N/A	

(Gartland & O'Shea, 2019 & 2020)

Co-benefits

The project has pilot character and has had the positive effect of further developing DH. The benefits are innovation and increased knowledge— the first of its kind in Ireland, improved building energy ratings and therefore increased building value, no carbon monoxide leak risks for residents (switching from gas), the pilot project character for the DH sector in Ireland (piloting contracts, procurement, technology, and thus a high learning potential), the innovative approach and transferability, and the knowledge share to all other pilot project cities in the EU HeatNet North-West Europe project. The large number of data centres in Ireland and across northwest Europe ensures a high replicability; the new way of contracting (fixed heat supply price and output-led specification) and the development of a contract template for local energy supply is now available for other public sector organisations to use. Finally, the visitor centre included at the energy centre for education, research, and training links with the local college (Gartland & O'Shea, 2019 & 2020).

5.5.6 Success factors and barriers

The analysis of the case study revealed the following key barriers and success factors:

Key challenges were to convince municipalities to become involved and be a driver of DH. The lack of awareness of DH and the capital requirement can be barriers if the benefits are not fully understood. Because it was the first of its kind, it was a challenge to future-proof waste heat supply works and that the infrastructure was in place to utilise the waste heat supply.

Selling the idea to customers to switch to DH instead of gas was difficult because customers are unfamiliar with DH. However, the project could point to DH being a proven technology elsewhere in Europe. Selling the idea to new developers to prepare for DH connection instead of installing their own heat equipment is a big advantage of DH for new development due to the cost-effective compliance with existing regulations when compared with technologies such as individual air source heat pumps.

Planning policy and regulations around installing DH pipes have been a challenge in this project, too. Given this is the first scheme of its kind in Ireland, there was a lack of clarity regarding the powers (Vires) of the council to install DH pipes in roads and for municipalities to supply the heat. It has since been assumed that under the Local Government Act and Local Government Reform Act 2014, the local authorities have the power to take measures or engage in activity that is necessary in the interests of the local community; these interests are defined as promoting social, economic, and environmental development, including providing utilities or equipment for specific purposes. Developing local DHC systems falls under this legal remit and, therefore, local authorities have the power to implement DHC schemes.

Several factors have been identified as key success factors:

Securing funding and peer-to-peer learning from the EU project helped to get the municipality stakeholders on board, which was important. Energy agencies and municipalities working together— energy agencies providing the required technical knowledge to assist contributed to success. Another key success factor was the planning condition that the data centre had to supply waste heat to a DH scheme. Additionally, several engagements with local building owners have been held to educate them of the benefits of low carbon DH supply; these engagements included face-to-face meetings and developing brochures that highlight savings and benefits for specific sites such as comparing options for new developments in terms of heating that will help them to meet the building regulations at the lowest cost to them. Working with government departments to allow municipalities the rights to install DH pipes was also key to the success of the project.

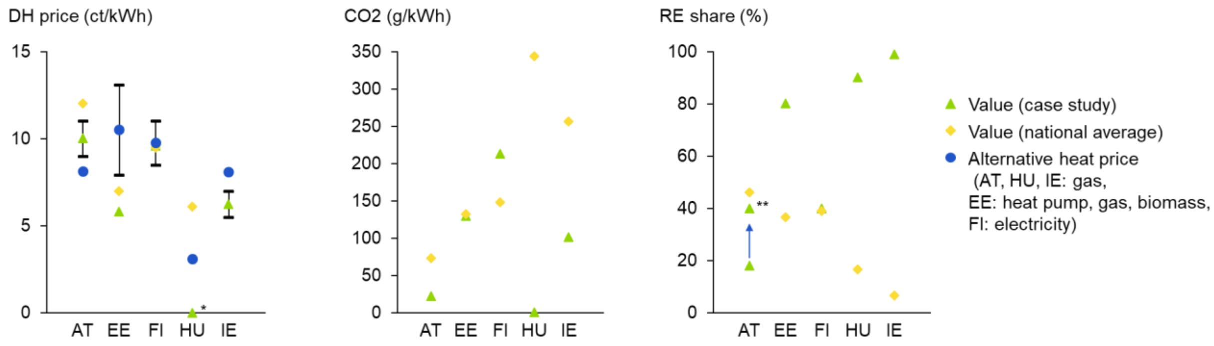
6. Benchmarking and key success factors

The benchmarking methodology is described in Chapter 3. The following sections present the benchmarking results, followed by explanations of the key success factors.

6.1 Benchmarking

Due to heterogeneity of the case studies, they are benchmarked against national averages instead of a cross-case benchmarking. Figure 5 illustrates the results of this benchmarking method.

Figure 5: Overview of case study key parameters benchmarked against national averages



* The DH price for Mórahalom (Hungary) is zero because the system produces heat for self-consumption in municipal buildings. Still, there are certain costs for the DH system (Heves, 2019 & 2020).

** In Austria, the renewable energy share improved from 18% to 40% within the case study. The national average is mainly influenced by rural biomass (Griessmair-Farkas, 2019 & 2020).

*** CO_2 emissions in Espoo (Finland) are currently higher than the national average, due to the higher share of coal in the local district heating system, which however, has been decreasing substantially since 2016. It is expected that this parameter will improve further in the next few years as more and more coal is being phased out of the Espoo district heating system.

The information is based on personal communication and discussion during the Steering Group meetings. (Heves, 2019 & 2020) (Kuusela, 2019 & 2020) (Luomala, 2020) (Keskivali, 2020) (Griessmair-Farkas, 2019 & 2020) (Gartland & O'Shea, 2019 & 2020) (Steering Group, Second steering group meeting, 2020) (Steering Group, Third steering group meeting, 2020).

Heat prices

In the left graph, DH prices from the five cases are benchmarked against national averages for DH prices and the most common alternative heating sources. Price intervals are given in the case of several common alternative heat sources in a country or local and national price differences (for alternative heat sources). The DH prices in the cases are generally competitive in a national context for all countries; however, the values also indicate that the competitiveness in relation to alternative heat prices heavily depends on context. This is because, for example, natural gas prices can differ by a factor of 3 between Member States (Eurostat, 2021) and also because relatively cheap alternatives are common in some countries (e.g. electricity and heat pumps in Finland). Overall, the figures indicate the cases are quite competitive, especially when considering their relatively good performance in terms of CO_2 emissions and renewable energy share compared to the national context, and also with a view to an increasing CO_2 price in the future.

In Ireland, no national DH price data was available, presumably due to the relatively new status of the technology.

CO_2 emission factor and renewable energy share

Figure 1 illustrates that CO_2 emission factors in the case studies are below (Austria, Hungary, Ireland) or on par (Estonia) with the national averages for DH. Only in the case of Espoo in Finland is the CO_2 emission factor higher than the national average. However, this will change by 2026 if the Espoo Clean Heat initiative is implemented according to plan. In terms of renewable energy shares in DH, three of the cases (Estonia, Hungary, Ireland) perform significantly better than the national average or at the same level (Finland). Only the Austrian case (Vienna) has a slightly lower renewable share than the national level, on the other hand, is the highest among the five national averages due to high shares of biomass in Austrian district heating systems (close to 50%) (BMK, 2020).

6.2 Key success factors

The success factors have been based on the analysed cases and discussed with the Steering Group (Steering Group, Second steering group meeting, 2020). The success factors can be allocated to five main categories:

6. Policy framework
7. Stakeholders, key drivers, and interplay
8. Political will and support
9. Positive vision and image
10. Economic aspects

Each of the main success categories contain several aspects:

Policy framework relating to the EU and national levels

Clear targets are important for setting a (long-term) direction for the development of a DH sector. Targets specifying the renewable energy share or CO_2 emissions reductions are well-functioning examples but targets directly addressing DH expansion have also been used. Integrating DH into local and national decarbonisation strategies to increase the renewable energy share in the heating sector can also be an effective political tool. Favourable investment and planning frameworks for DH are essential for expansion. Successful examples address both the competitiveness of DH and the expansion of low carbon DH. A connection requirement or preferred areas (zoning) for DH networks (where competitive) have provided planning and investment security. Customer protection (especially in the case of mandatory connection to the network) by regulating prices and profits has been essential for maintaining trust in DH.

Stakeholders, key drivers, and interplay

Especially at the local level, identifying stakeholders and their key drivers and interests has been important for establishing successful collaborations around DH. Cities are often important key stakeholders with different roles in different contexts—e.g. as strategic planning entities, permitting authorities, operators of DH systems, and suppliers of waste heat. In successful DH systems, there is often a productive interplay and collaboration between local authorities, operators, and industries.

Political will and support

Local political support is important for processes, approvals, providing space for equipment, and DH zoning. Local funding can be an important driver and local political support for long-term use of DH is important due to the high upfront costs and long lifetime of DH infrastructure.

Positive visions and image

Strong positive visions and narratives for DH follow from supportive political frameworks and successful local collaboration and are important for maintaining a positive image—e.g. DH as a key technology for decarbonisation, bringing renewable energy cost efficiently to the city. Success stories and pilot projects help build positive narratives. The Vienna large-scale heat pump (HP) with 40 GW is a good example. Cities and district operators can also benefit from consistent and continuous communication about the advantages of DH. Direct engagement with local building owners can help build trust and spread knowledge (e.g. regarding the benefits of a low carbon DH supply).

Economic aspects

Funding has been important for establishing new DH networks. Prior to that, funding was also crucial to expanding the knowledge of funding possibilities. In the case study from Hungary, the DH project supporting the local economy is an important co-benefit. Successful projects thrive on planning security for long-term investments by means of long-term contracts. Another key success factor is if the investment cycles of the operator are matched (investments in renewable energy together with upgrades of old production infrastructure). From an operator perspective, diversifying the portfolio by investing in renewable heat sources increases the economic robustness of the system because it decreases the system's dependence on gas or oil (prices).

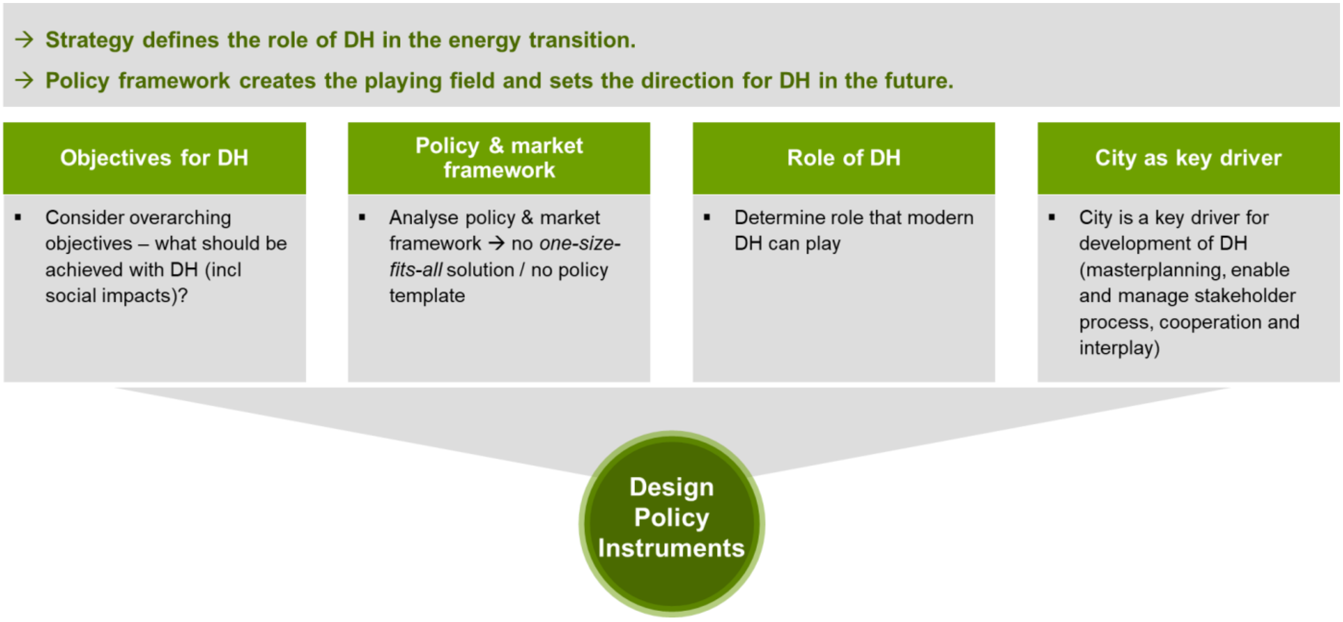
7. Policy recommendation and complementary measures

The outcome of this chapter is based on broad discussions that happened mainly in two meetings (Steering Group, Third steering group meeting, 2020; Steering Group, Second steering group meeting, 2020). For the development of the policies there has been followed a two-step approach, where in a first step key aspects for policy recommendations had been identified and, on this basis, recommendations along these key aspects had been developed.

7.1 Relevant aspects for the design of DH policies

Relevant aspects for designing polices are the overarching objectives and possible contribution of DH to these objectives, the policy and market framework, the role DH can play in general, and the city as a key driver for the development of DH. Figure 7 gives an overview of the key aspects to consider.

Figure 6: Illustration of relevant aspects for the design of DH policies



7.1.1 Objectives

DH plays an important role in the future energy transition and is a well-suited instrument for decarbonising cities and for bringing renewable energy into the city.

DH is an instrument to help decarbonise cities and secure a clean heat supply. Customer protection is important and should be supported through a competitive, fair, and transparent service. DH can be an economically feasible solution and can bring social benefits such as job creation, improved health, comfort, and convenience. With the right framework, DH can cost-efficiently achieve comfortable and clean heat for low-income households (reduce energy poverty and heat costs with renewable energy).

7.1.2 Policy and market framework

DH is local; in terms of policy and market frameworks, there is no one-size-fits-all solution, as these systems have to take the local conditions into account, including network size, local resources, and building and customer characteristics.

On a general level, some technical and economic properties of DH apply to all DH systems, while other properties are highly context dependent. Therefore, the overall policy recommendations presented in this section will often have to be made specific to the respective (national) context.

General features of DH grids

DH grids and DH production facilities are *place bound*, meaning that DH cannot feed into a national grid (like gas or electricity), and that to achieve high shares of DH in a country, many separate local DH networks at a town or city level need to be established. While existing DH networks to some extent still run on fossil fuels, many have begun to integrate local heat sources, such as waste heat, biomass, geothermal heat, solar heat, or ambient heat (e.g. groundwater). The design of DH networks will, to a higher degree, depend on the type and availability of local heat sources. DH networks often depend on a high heat demand density to function optimally, meaning that the customer connection rate in the network should be as high as possible. This also means there is a mutual dependence between customers: if many (especially large) customers leave the DH network, it will negatively affect the service and quality of DH for the remaining customers.

Regulators and DH operators have to strike a balance between the high levels of customer choice and competition, and ensuring the future feasibility and efficiency of DH systems.

In terms of competition, the choice for customers between DH and alternative heating solutions is greatest prior to the decision to join or not to join the DH network or when a new DH network is being established. Once the network is in place, DH suppliers are often in a market dominating role because it is usually not possible or feasible for customers to choose a different DH supplier and even less so a different network within their area. Switching back to an individual heating solution is also connected to high transaction costs for the customer; however, many countries have made it possible for customers to disconnect, sometimes with the condition that cheaper or more sustainable solutions are available.

Policy frameworks should be designed to respond to the specific status and challenges of national DH systems.

The national policy framework and regulatory environment have a high impact on the feasibility of DH through the design of market and planning conditions. Taxation on fuel, electricity, waste heat; subsidies and incentive schemes for CHP and renewable energy in DH; and the framework for spatial (heat) planning in regions with municipalities have a direct impact on the competitiveness of DH. While DH has to live up to multiple objectives in terms of climate, economy, and society, the optimal combination of regulatory mechanisms to achieve these objectives and support the expansion of DH networks depends on the national starting point:

- ***Newcomer countries*** with few or small DH grids may focus on incentivising upfront investments and high connection rates to ensure fast establishment of new, efficient DH grids.
- ***Countries with old DH grids*** may focus on incentivising refurbishment of grid infrastructures and switching to renewable fuels DH plants, as well as on building energy efficiency.
- ***Countries with modern DH grids*** may focus on further increasing the efficiency of DH along with increasing and maintaining high service levels and customer satisfaction.

The difference of DH markets in Europe lies in the focus and degree of the regulation.

The nature of DH grids does not allow for the same level of liberalisation and unbundling as, for example, in the electricity and gas sectors. Once established, DH grids and operators are naturally predominant in certain areas, which at a minimum requires transparent and fair market conditions to strengthen consumer rights and to enable a continuous improvement of DH systems. To that end, several different price and profit regulation regimes are in use across Europe (see e.g. (Odgaard & Djørup, 2020)). The main difference in these regimes lies in the degree of freedom for DH companies to set DH prices and to earn a profit from their business. According to Hvelplund and Djørup (2019), fair and transparent conditions for consumers are either supported by public (e.g. municipal) and consumer ownership of DH systems or, in the case of commercial ownership, they need to be safeguarded by central regulation and monitoring to a larger degree.

Two overall price and profit regulatory regimes can be distinguished, in between which mixed approaches are being applied in different countries:

- **Consumer profit regimes:** Sometimes understood as nonprofit, which is not correct, as DH operators are allowed to make a profit, which (partially) has to be paid back to the consumers. This regime has attracted consumer ownership (cooperatives) and public ownership (municipal energy companies), as in the example of Denmark.
- **Commercial profit regimes:** DH companies are allowed to earn and keep a profit. This regime is usually associated with lower degrees of regulation that either caps DH prices or exposes DH companies to greater competition (from alternative heating solutions), as in the examples of Sweden and Finland.

Finally, a **third regime** can be imagined in which DH may be treated as a public service obligation (under an actual nonprofit regime). However, such a regime could not be identified in any of the studied countries.

Figure 7: Anchor points for regulators to ensure fairness and transparency in DH

7.1.3 What is the role of DH in the future energy system?

DH can play a key role in the energy transition. DH can contribute to decarbonisation targets and provide flexibility (backbone for the renewable energy system).

DH can contribute to climate and renewable energy targets (in 2050). As a future energy hub, it can accommodate all kinds of renewable energy (integrative function). In this function it can enhance supply security (digital and smart; e.g. heat buffers, load management, peak shaving), provide flexibility to the heat and electricity grids via integration (react to surplus electricity/heat), integrate diverse heat sources (including low temperature and excess heat) and local energy resources, support sector coupling and integrate excess electricity (large heat pump (HP)), and interact with Power to X (PtX) and biogas systems (Lund, et al., 2014).

DH systems can also react to a city's needs (demand side). Therefore, DH systems need to adapt to lower demand in the future (low energy buildings) and also need to integrate the demand side (DH systems and building mass as one system).

The business model of DH systems is changing from central to open grid solutions and competitive systems, which may require transitional agreements with existing suppliers. It also changes from operator to customer focused, with a focus on service and building energy efficiency.

7.1.4 City is the key driver

While the European Commission and the Member States need to set the framework for DH, the city is key for implementation. Policy should enable cities to become key drivers. The city drives planning processes, is responsible for master planning, sets local frameworks, and drives stakeholder cooperation. It increases transparency, enables access to data, executes feasibility studies, facilitates communication and processes, and may have local resources available. Cities also enable implementation (provide technical assistance) and focuses on the local value chain and social benefits.

7.2 Policy recommendations

The policy recommendations had been developed and broadly discussed with the Steering Group. It has been decided to group the recommendations in the following categories: targets, strategy & planning, policy and market framework, financial incentives, information & governments (Steering Group, Second steering group meeting, 2020) (Steering Group, Third steering group meeting, 2020).

7.2.1 Targets, strategy, and planning

There is a strong need for national targets and strategies for DH since it strengthens the role of DH and enhances its role for reaching decarbonization targets.

The EU, Member States, and city level should embed DH in energy strategies and climate plans (heat strategy, zero/low carbon roadmap). They should include DH in scenario calculations to enhance its role in the future energy transition, with a focus on decarbonisation, flexibility, and smart grid as well as social benefits. In the context of 2050 targets, it should include the transition to zero carbon DH (in the context of zero carbon heat), set renewable energy and CO_2 emissions targets for DH, and strengthen the potential role of DH in overall smart grid and flexibility considerations.

The reason why setting targets and embedding DH in strategies is important is that:

i) it gives clear signals to the DH operators and other stakeholders (e.g. housing associations);

ii) it strengthens the role of DH in the context of decarbonisation objectives;

iii) it enhances the importance of locally available renewable energy resources for DH; and

iv) it enhances the potential contribution of DH to energy and climate targets.

On a Member State and city level, national governments should introduce requirements for comprehensive, green local heat plans (as part of integrated local energy plans), including improved energy efficiency of the building mass. Where applicable, national governments should consider DH zoning and possibly mandatory connection depending on the policy framework. DH zoning is mostly important for new DH systems to ensure investment security and also to ensure large enough DH grids benefitting many consumers instead of suboptimal mini-DH grids benefitting only a few. Apart, city heat planning should be introduced, and local authorities should draft comprehensive, green heat plans (together with local actors) and revise periodically. Finally, local authorities should define DH zones in relation to these local heat plans.

7.2.2 Policy and market framework

Modern, efficient district heating based on renewable energy is an effective measure to decarbonize cities but requires clear policy and market frameworks to be exploited and diffused optimally. To create fair conditions, district heating should be supported and regulated on par with alternative heating solutions to create a level playing field. While at the EU level it should be ensured that the ETS effectively supports the diffusion and decarbonization of district heating, national governments should:

Ensure that taxes and subsidies related to district heating technologies are at the same level as for alternative heating technologies. This should also include uniform treatment and accounting of district heating in national and local strategies as well as project appraisals (e.g. through primary energy factors) to reflect the actual contribution to decarbonisation strategies in a uniform way.

National governments should also ensure that regulation for district heating (and alternative solutions) takes the transition of the entire energy system into account, supporting synergies with other energy sectors and limiting unwanted lock-ins. For instance, district heating development should go hand-in-hand with strategies to improve the energy efficiency of the building stock (renovation wave) and sector integration (e.g. of excess renewable electricity).

Market regulation – two regimes

In the following, recommendations and examples for the two profit and price regulation regimes (commercial profit and consumer profit) are given. As mentioned, the regulatory regimes directly impact fairness and transparency, but also indirectly determine to what extent and how district heating operators and customers can participate in the green transition (by, for instance encouraging network and building level energy efficiency and investments in renewable energy technologies). The following general recommendations for both profit and price regulation regimes have been identified:

Policy instruments for the transition to efficient and zero-carbon district heating should be introduced, e.g. maximum allowed CO_2 factors, which are being reduced over time (analogue to the renovation wave which introduces Minimum Energy Performance requirements (MEPS) for renovation of buildings).

Countries should ensure that clean, low-cost heat sources can enter the district heating system through e.g. the facilitation of industrial symbiosis and agreements with suppliers of (low temperature) excess heat.

Specifically, in consumer profit regimes national governments should:

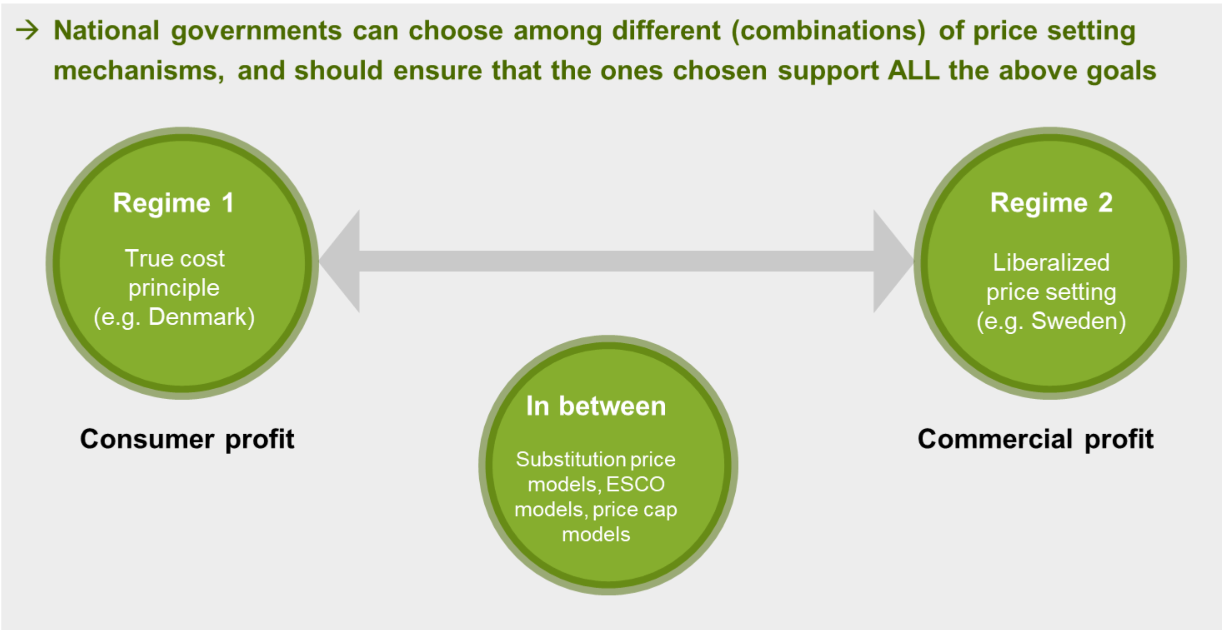
Ensure consumer protection and progress with the green transition through fair and transparent rules for district heating price setting (such as the true cost principle), where, as a basis, consumer prices match district heating production costs. To ensure efficiency improvements and further investments in renewable energy the true cost principle can be supplemented by a regulated profit (for instance, earmarked to energy efficiency and investments in renewable energy). Furthermore, countries can facilitate consumer power and trust by strengthening (local) public ownership of district heating systems (municipality or consumer ownership). Finally, building energy efficiency needs to be stimulated, especially in areas with cheap district heating and/or an old building stock.

<u>In commercial profit regimes with liberal price setting national governments should:</u>

Establish clear monitoring of district heating prices and ensure price transparency for consumers. These can be supplemented with price control mechanisms, such as district heating price caps or price negotiation. However, here it is also essential that adequate incentives for improving the energy efficiency of the building stock are in place for, both, customers and district heating operator. Many existing district heating pricing mechanisms do not effectively promote (building level) energy efficiency due to their orientation towards district heating sales.

Figure 7 illustrates the two generic price and profit regulation regimes and the various mechanisms that can lie “in between” (see e.g. (Odgaard & Djørup, 2020)). For instance, instead of a pure true cost principle or liberal price setting, it can be opted for price cap models, in which the price of the best available alternative sets the limit for the maximum district heating price (for example in Norway and the Netherlands). In other set-ups, ESCO[3] models may be chosen to facilitate upfront investments and stable district heating prices during the first years of operation.

Figure 8: Different price setting mechanisms, inspired by: (Odgaard & Djørup, 2020)



[3] ESCO: Energy Service Company. An ESCO typically establishes, owns and/or services a production facility at the building or production site, getting its costs covered through an energy service purchase agreement with the customer.

7.2.3 Financial incentives

When it comes to creating a favorable business environment for district heating, *direct measures* and *indirect measures* should supplement each other. Indirect measures like the EU Emissions Trading Scheme (ETS) can in general create favorable conditions for investments in green energy and energy efficiency - including (inside) district heating areas - but require high and stable enough CO_2 prices to be effective. Taxes on fossil fuels are a good and important supplement to a necessary, well-functioning ETS, while also accelerating the phase out of inefficient (individual) heating systems. This is especially important in district heating systems where private (shareholder) capital is available, as it can help steer investments in a climate-friendly direction. Furthermore, fuel taxes can be designed in accordance with the climate-policy context and fiscal environment of the individual member states. Direct measures can take the form of funding programs and subsidy schemes and are especially important for the implementation new district heating systems and technologies. This can be a good initial help for systems with limited start-up capital, for instance, in the public sphere.

Moreover, financial incentives should not only be geared towards investments in *district heating technology and infrastructure*, but also towards *developing the necessary implementation capacities, planning frameworks and socio-cultural environment*.

Financial incentives to support development of new district heating systems and/or green investments in existing district heating systems can be designed at the EU, national and city levels and can target different kinds of challenges.

At the EU level, funding should target the sharing of knowledge between member states and national/local capacity building within assessment and planning tools, and business models. Recent examples include the HeatRoadmap Europe[4], HOTMAPS[5], THERMOS[6], REWARD-Heat[7], projects and others. Topics deserving greater focus in that respect are regulation and customer engagement and protection. Funding should also focus on establishing national pilot and lighthouse projects that:

- Increase the efficiency of district heating
- Accelerate the decarbonization of the sector
- Foster stakeholder corporation
- Develop strategic and integrated heat planning linking up with the other energy sectors (sector integration)
- Foster citizen involvement, help build district heating cultures and trust, and improve the image of district heating

At the national level, funding should further target:

- High upfront investment costs (network & grids, in newcomer regions & countries) through e.g. support for investments in state-of-the-art district heating infrastructure. Public loan guarantees and facilitation of ESCO models can also be adequate instruments in this regard.

[4] https://heatroadmap.eu/
[5] https://www.hotmaps-project.eu/
[6] https://www.thermos-project.eu/home/
[7] https://www.rewardheat.eu/en/

- Low temperature district heating in combination with building energy retrofits and renovation, to simultaneously decrease the carbon footprint of, both, district heating and the building stock.
- In addition to public loan guarantees access to low interest public loans for public district heating companies can be facilitated to reduce initial investment risks.
- Technical assistance for e.g. feasibility studies and investment appraisals, as these competences often either lack or are expensive to acquire in smaller towns and district heating systems.
- Development of heat planning frameworks and guidelines to provide a clear direction for local authorities and district heating operators regarding e.g. the spatial planning of district heating areas.
- Heat planning tools and procedures, such as heat maps and heat atlases for strategic heat and energy planning that facilitate resource and demand assessments and network expansion planning.
- Funding for pre-feasibility studies such as test drillings for geothermal heat to decrease the very high start-up risks connected to this and similar technologies in some countries.
- Promotion of citizen- and community-driven district heating projects to help build trust in the technology and to support a just transition.

At the city level, funding should focus on:

- Projects integrating building renovation and (low temperature) district heating expansion.
- Inclusion of low-income and vulnerable citizens into district heating systems at fair prices and with a view to bringing down energy poverty where relevant.
- Promoting citizen- and community-driven district heating projects and strengthening consumer involvement and decision power in district heating companies to build broad societal trust and support for district heating.

7.2.4 Information and governance

Besides financial incentives, adequate market frameworks, planning frameworks, and long-term objectives, there is a significant potential and a need to increase the knowledge of and familiarity with DH in the EU. Besides its technical and economic attractiveness, DH can sometimes be overlooked or evaluated differently in similar contexts due to a lack of information and trust in the technology. Furthermore, national and local capacity building and measures to ensure transparency, fairness, and green transition objectives should be continuously monitored. The following recommendations address these issues.

At the EU level:

→ Progress with transparency, fairness & the availability of information in the district heating sector should be monitored.
→ Overall guidelines for developing adequate metrics and parameters (e.g. costs and prices) for the assessment of district heating and alternative solutions should be developed.

In terms of project assessment and planning, national governments should:

- → Ensure that calculation rules and available data for project assessment and feasibility studies, support a low-carbon 2050 energy system, by, for instance, providing national technology catalogues and project assessment guidelines (see also below).
- → Streamline assessment methodologies (e.g. primary energy factor) and improve data availability for project assessment
- → Providing socio-economic parameters for project assessment, including environmental, job creation and supply security parameters to support uniform assessment of district heating across the country. These can also include standard calculation inputs, such as discount rates and CO_2 prices.
- → Build technology catalogues[8] including investment + operation and maintenance costs, emission values, efficiencies etc. for a range technology relevant for district heating and/or the energy sector as a whole.
- → Facilitate access to detailed demand data (heat demands) and resource assessments (heat sources), which improves the level of detail of heat planning and thereby, also investment security. This can to some extent be achieved by facilitating the use of heat atlases/heat maps and access to building-level heat data in e.g. national and local building registers/databases.
- → Stimulate the establishment of national district heating boards and associations for better access to and exchange of knowledge and support for district heating operators and other stakeholders.
- → To support citizen- and community-driven district heating projects technical assistance groups can help with project start-up and providing the initial technical know-how.

In terms of fairness, transparency and consumer influence, national governments should:

- → Set up public (cost and) district heating price databases and collect technical and economic data from district heating suppliers regularly to ensure consumers and suppliers can compare and follow the development of (costs and) prices.
- → Establish clear rules for data provision and transparency from district heating suppliers and sub-suppliers, which can also include clear rules regarding depreciation, inter-corporation interest rates etc. The latter is especially relevant in countries using regulated profit regimes.
- → Introduce consumer and local authority representation in district heating company boards to increase the proximity of consumers to investment and pricing decisions in district heating.

Cities should aim for:

- → Supporting long term urban (district) heating strategies by effective citizen engagement focusing on inclusive and participatory approaches (e.g. co-creation), which can make DH compatible with local needs.
- → Active representation in district heating company boards (granted/enabled by national government) to not only ensure fair and transparent operation, but also to support long-lasting and constructive collaboration with district heating operators.

[8] An example is the Danish Energy Agency's Technology Catalogue: https://ens.dk/en/our-services/projections-and-models/technology-data/technology-data-generation-electricity-and

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