European Commission

Overview of District Heating and Cooling Markets and Regulatory Frameworks under the Revised Renewable Energy Directive

Annexes 6 and 7
Final version

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District Heating and Cooling in the European Union

Overview of Markets and Regulatory Frameworks under the Revised Renewable Energy Directive

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List of acronyms

ADEME	Agence de l'Environnement et de la Maîtrise de l'Energie (French agency for environment and energy management)
AGFW	Energieeffizienzverband für Wärme, Kälte und KWK (German energy efficiency association for heating, cooling and CHP)
APG	Algemene Pensioen Groep (Dutch Pension Fund)
Art	Article
ATES	Aquifer Thermal Energy Storage
AVBFernwärmeV	Verordnung über Allgemeine Bedingungen für die Versorgung mit Fernwärme (Ordinance on General Terms and Conditions for the Supply of District Heating Germany)
BTES	Borehole Thermal Energy Storage
CAPEX	Capital Expenditure
CAPM	Capital Asset Pricing Model
CCS	Carbon Capture and Storage
CHP	Combined Heat and Power
COC	Condensable Organic Compounds
COP	Coefficient Of Performance
CoP	European Statistics Code of Practice
COx	Oxides of Carbon
CPC	Compound Parabolic Collector
CSP	Concentrated Solar Power
CTR	Centralkommunernes Transmissionsselskab I/S (Metropolitan Copenhagen Heating Transmission company)
DC	Distrcit Cooling
DCS	District Cooling Systems
DH	District Heating
DHC	District Heating and Cooling
DHW	Domestic Hot Water
DN	Nominal Diameter (in mm)
EC	European Commission
ECJ	European Court of Justice
EED	Energy Efficiency Directive
ELAN	Evolution du logement de l'aménagement et du numérique (Evolution of housing, development and the digital environment)
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Coefficient
EPCC	Engineering, Procurement, Construction and Commissioning
ESIF	European Structural and Investment Funds

ESP	ElectroSubmersible Pump
ESS	European Statistical System
EU	European Union
EWRC	Energy and Water Regulatory Commission (Bulgaria)
GHG	GreenHouse Gases
GW	GigaWatt
GWB	Gesetz gegen Wettbewerbsbeschränkungen (Act against Restraints of Competition in Germany)
GWh	GigaWatt hour
HC	Heating and Cooling
HeizkostenV	Verordnung über Heizkostenabrechnung (Ordinance on the Settlement of Heating Costs)
IHP	Independent Heat Producer
kW	KiloWatt
kWh	KiloWatt hour
L-CNG	Liquid to Compressed Natural Gas
LNG	Liquefied Natural Gas
MID	Measuring Instruments Directive
MS	Member State
MW	MegaWatt
MWe	MegaWatt electric
MWh	MegaWatt hour
MWth	MegaWatt thermal
na; n/a	not available
NCC	National Commission on Energy Prices (Lithuania)
NECP	National Energy and Climate Plan
NERC	National Energy Regulatory Counci (Lithuania)
Nm3	Normal cubic meter
No.	Number
NOx	Oxides of Nitrogen
NRA	National Regulatory Authority
NUP	National Urban Policy
nZEB	nearly Zero Energy Building
OPEX	Operational Expenditure
ORC	Organic Rankine Cycle
P2P	Point-to-Point
PEC	Primary Energy Consumption
PM	Particulates Matter
pp	Percentage Points
RED	Renewable Energy Directive

RES	Renewable Energy Sources
RES-HC	Renewable Heating and Cooling
SCR	Selective Catalytic Reduction
SNCR	Selective Non-Catalytic Reduction
SOx	Oxides of Sulphur
TO4	Thematic Objective 4
TPA	Third Party Access
TPS	Third Party Supplier
TSO	Transmission System Operator
UK	United Kingdom
URE	Energy Regulatory Office Electricity (Poland)
URSO	Úrad pre reguláciu sieťových odvetví (Office for Regulation of Network Industries Slovakia)
VAT	Value Added Tax
VEKS	Vestegnens Kraftvarmeselskab I/S (DH Company Copenhagen)
VOC	Volatile Organic Compounds
VST	Vilniaus Šilumos Tinklai (DH Company in Lithuania)
WWTP	WasteWater Treatment Plant

Annex 6: Case study analysis on the integration of renewable and excess energy sources in DHC systems

A case study method has been retained to illustrate how renewable and waste heat or cold sources are being integrated into some of the most efficient DHC networks in Europe.

This approach enables to illustrate the specific technical, economic, regulatory and operational enablers of ten DHC systems in operation within different geographies and contexts. It also displays strategic decisions made to reach a significant share of renewable and waste energies in their energy mix, as well as development paths followed towards decarbonisation, identifying replicable success factors.

This section presents the methodology of the analyses and 10 detailed case studies, while the conclusions are part of the Main Report of the study (Section C.2).

6.1. Methodology for case study selection

The first step of the analysis consisted in choosing the right case studies, providing sufficient insights on different technologies, models and patterns followed DHC systems in Europe in order to integrate RES and waste heat and cold sources, in particular those presented in this study (cf. Section C.1 of the Main Report). The selection followed 3 main stages.

Identification and contact of potential case studies

To identify potential case studies, the authors performed a thorough literature review, contacted national and EU DHC associations, DHC companies and other DHC professionals within their network, and published a call for case studies in cooperation with the Celsius Initiative[1]. They also relied on their own, first-hand operational knowledge of efficient DHC systems.

Based on this first review, a **preliminary questionnaire** was developed including the main specific criteria to take into account for the selection of case studies. In particular, a set of questions and indicators was defined to assess:

- The performance of the network in terms of economic viability, final price for consumers, innovation, heat market share, competition, energy mix, environmental aspects and replicability; and
- The complementarity of the case studies in terms of geographical coverage, type of network, ownership and business model, regulatory framework, energy sources and technologies used, customer structure, additional value brought by the DHC system to the community or other particular aspects of interest (e.g. fuel switch long-term strategy, compatibility with highly efficient buildings, synergies with the electricity sector, etc.);
- The data availability and willingness to collaborate in the study, if selected.

The answers to the preliminary questionnaires were analysed and the most relevant ones were integrated in a worksheet providing the main characteristics and key indicators of the **preselected DHC networks**.

[1] https://celsiuscity.eu/

Evaluation of preselected case studies

At a second stage, the preselected DHC networks were benchmarked against a set of criteria to assess their **performance** and to identify the specific features contributing to achieving a representative a **complementary** group of case studies. The specific criteria are indicated in Figure 1.

Best Performers

Performance indicators	Range of values	Weighting	Benchmark*
1. Economic viability	Y/N		-
Robust business model	Y/N		-
2. Price competitiveness (1)	[0,100]	15%	
Average price of heat (EUR/MWh, PPP adjusted)	[1,5]		quantitative (1)
3. Innovation	[0,100]	15%	
Policy design/legal framework	[1,5]		qualitative
Technology	[1,5]		qualitative
Environment & Social	[1,5]		qualitative
4. Stable or Growing market	[0,100]	10%	
Stable or growing market share for DHC	[1,5]		qualitative
5. Competitive market	[0,100]	10%	
Competition exists in practice between different heat & cold producer companies	Y/N		-
Regulation allows new heat / cold producers to join the network	Y/N		-
6. Environmental performance (2) (3)	[0,100]	20%	
CO_2 emissions ($kgCO_2$/MWh heat, cold supplied)	[1,5]		quantitative (2)
Renewable and surplus heat fraction (%)	[1,5]		quantitative (3)
7. Replicability	[0,100]	20%	
Type of network (i.e. H/HC; size; urban framework)	[1,5]		qualitative
Policy design/legal framework	[1,5]		qualitative
Business model	[1,5]		qualitative
Technology	[1,5]		qualitative
Complexity **(4)**	[1,5]		qualitative (4)
8. Willingness to cooperate / reactivity	[0,100]	10%	
TOTAL SCORE	[0,100]	100%	

Complementary Group

COMPLEMENTARITY CHECK
1. **Geographical coverage:** The Southern, Western, Northern, Eastern and Central Europe should be covered in at least one case study each
2. **Type of network:** different types of energy supplied (i.e. heating or heating and cooling), different scales and urban frameworks, governance, age...
3. **Regulatory framework:** case studies both within regulated and un-regulated heat markets, different TPA models
4. Balanced coverage of the main **customer structures** (residential, service, and industry)
5. **Diverse sources of heat/cold supply and technologies:** e.g. co-generation, renewable energy (e.g. geothermal, solar, biogas...), waste heat/cold from different sources (industries, water bodies, data centres....), heat pumps, thermal storage, etc.
6. Showcase of different forms of **additional value brought by the DHC system,** e.g. synergies with other local initiatives and infrastructure (local energy transition strategy, sector integration, energy efficiency in buildings...), enabling new energy management and energy efficiency services, creating value for local communities, etc.

Figure 1: Criteria for case studies selection

The **performance** assessment covered the 8 areas listed below. The benchmarks and weighting of each criterion were jointly agreed between the authors and the European Commission.

1. Economically viable business (necessary condition)
2. Price competitiveness against alternative solutions
   – Average price of heat, Purchasing Power Parities adjusted (EUR/MWh)
3. Innovation
   – Number and quality of innovative features in the business model with regard to i) policy / legal framework; ii) technology; iii) environmental and social aspects
4. Stable or growing market
5. Competitive market
   – Competition exists in practice between different heat production companies
   – Regulation allows new heat producers to join the network
6. Environmental performance
   – CO_2 emissions ($kgCO_2$/MWh heat, cold supplied)
   – Use of renewables and waste heat/cold (%)
7. Replicability potential
   – In terms of i) type of network; ii) policy design/legal framework; iii) business model; iv) technology; v) complexity (e.g. number of actors involved, coordination efforts…)

8. Willingness to cooperate and actively contribute to the study

As a result, the preselected cases obtained a **performance score**, allowing to establish a comparison and ranking of the DHC systems regarding their suitability to participate in the case studies analysis.

Other than performing well, the selected case studies had to be **representative** and **complementary,** showcasing diverse characteristics from a technical, urban, climate, economic and financial perspective. This was translated into 6 additional conditions to be fulfilled by the final group of case studies:

- Geographical coverage: The southern, western, central and northern EU regions should be covered in at least one case study each;
- Type of network and business model: different types of energy supplied (i.e. heating or heating and cooling), different scales and urban frameworks, different governance modes (public, consumer-owned, Public Private Partnership, private);
- Regulatory framework: the group should include case studies operating in locally-regulated heat markets and in heat market with nationally centralised regulation;
- Balanced coverage of the main customer segments (residential, service, and industry);
- Diverse sources of heat/cold supply and technologies: e.g. cogeneration, renewable energy (e.g. biomass, geothermal, solar, biogas...), waste heat/cold from different sources (industries, data centres, transportation networks…), heat pumps, thermal storage, etc.
- Different forms of additional value brought by the DHC system (e.g. synergies with other local initiatives and infrastructure, fuel switch long-term strategy, compatibility with highly efficient buildings, synergies with power system, enabling new energy management and energy efficiency services...)

Selection of the final group of case studies

This evaluation was performed on the 15 preselected networks, and enabled the authors to select the final group of 10 case studies (in 9 countries), resulting in the final group retained in the study:

- Odense (DK),
- Copenhagen (DK),
- Helsinborg (SE),
- Greater Bordeaux (FR),
- Querfurt (DE),
- Aranda del Duero (ES),
- London (UK),
- Graz (AT),
- Jelgava (LV),
- Plock (PL).

6.2. Methodology for case study analysis

The case study analysis is mainly based on literature review, discussions with local actors identified for each case study and, for some cases, site visits.

The main steps followed for undertaking these analyses are described below.

1. First of all, a **detailed questionnaire** was developed and validated by DG ENER, covering all the topics to be analysed. This questionnaire was shared with the contact person of each case study to identify the most appropriate actors (stakeholders) and people within the city or utility under study to answer each of the ca. 80 questions, covering the following topics:

    A. National Context

    B. Local Context
    - City context
    - Heating (and cooling) market(s)

    C. Governance and business model
    - Presentation of the DHC system
    - Organization and governance of the DHC system
    - Strategy and offer (strategy in place, services provided and prices)
    - Financial model (tariffs and fees, financial results…)

    D. Use of RES and waste heat/cold sources
    - Historical milestones of the integration of these sources
    - Technical, economic, operational and contractual considerations

    E. Sector integration and Local value creation
    F. Prospects
    G. Conclusion: Key Success Factors and Replicability

2. An exchange on the basis of this questionnaire enabled the team to identify **relevant documents and information to analyse before the main interviews / site visits**, and to schedule those meetings with the main local contacts participating in the case studies.
3. **Site visits** of 1 day were organised when needed and possible, as the case studies were realised during the Covid-19 pandemic. These visits included **meetings** with DHC grid operators (and, where relevant, their consultants), local authorities, as well as **visits to the DHC facilities** (production plants and control rooms).
4. The case study analysis reports were shared with the main **local contacts** interviewed, for their **review**.
5. Finally, the analysis was reviewed and validated by DG ENER.

6.3. Case study Odense (DK): integrating waste heat from a large data centre

6.3.1. National context

District heating is the leading solution in the Danish heating market, where DH grids are mostly decarbonised and community-owned (see Table 1 below). Indeed, the decarbonisation of H&C is one of the pillars of the Danish ambition for reducing CO_2 emissions by 70% in 2030 (compared to 1990 levels), when Denmark aims at being independent from fossil fuels for heating and electricity. Current efforts in this field are mainly focused on **planning the natural gas phase out through a large-scale switch to DH or individual heat pumps** following a comprehensive energy planning done at district and city levels, while progressively decarbonising existing DHC systems.

Table 1: Key facts for DHC in Denmark

DHC in Denmark - Key facts		
Regulation	Regulator / Supervision authority	• Danish Utility Regulator (*Forsyningstilsynet*) • Other authorities: Energy Supplies Complaint Board (*Ankenævnet på Energiområdet*): issues complaints not regulated by the heat supply act
	Role of municipalities	• Most municipalities own their public utilities • Develop and review the local heat plans, approve new projects when they have the highest socioeconomic benefits
	Ownership (in terms of capacity, 2019)	• Municipality owned companies (60%) • Consumer-owned cooperatives (35%) • Private companies (5%)
Incentives	DHC support schemes	• Environmental taxes • Heat Supply Act (1979) • Local heat plannings as part of urban planning • Energy Savings Obligation Scheme (2006) • Electricity production subsidy for CHP using RES • Direct premium tariff for use of biogas • RES exempted from fossil energy taxes
Market	Total DHC sales to customers (2017)	• DH: 30 391 GWh • DC: 4 147 GWh
	Main clients (in terms of sales, 2017)	• 65% residential, 30% tertiary, 5% industrial
	Main operators (in terms of turnover, 2017)	• Municipality owned companies: HOFOR, AffaldVarme Aarhus, VEKS, Fjernvarme fyn, Aalborg, TVIS, Vestforbraending

The case of **Odense** illustrates how the city and its neighbouring communities are approaching the decarbonisation of their DH network, valuing the synergies with the electricity and other sectors, and implementing one of the world's largest waste heat recovery project with heat pumps, recovering excess heat from a large data centre.

6.3.2. Local context

Odense is the third largest city in Denmark, and since 2012 it has set ambitious energy transition objectives, aiming at reaching a **100% renewable primary electricity and heating supply by 2030** (except for back-up supply). The city's Urban Strategy of 2019 provides the details of the priority intervention areas and projects contributing to its sustainable development until 2030[2], in line with the national objectives mentioned above, and including an objective of coal phase out by 2023.

[2] https://www.odense.dk/byens-udvikling/byens-vision (in Danish)

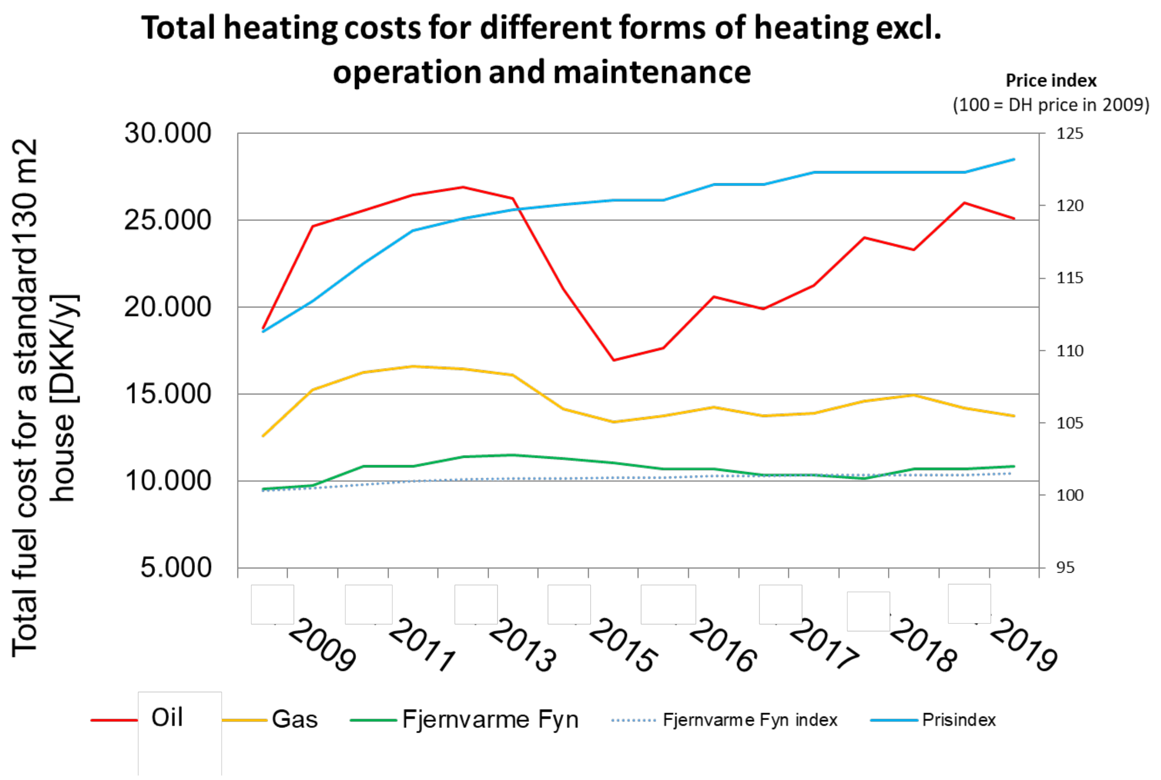
Table 2: Key urban indicators for Odense

	Odense City – Fyn island	
Statistics (2019)	Population (2020)	204 895
	Demographic trend (2016-2020)	+ 0.74 %/year
	Density (2020)	673.2 inhab./km²
	Housing (number of dwellings, 2020)	99 529
	Housing in multi-flats buildings (2020)	41 922
	Heating degree days (T_{ref} = 15°C)	3 720
Regulation	Building regulation (national)	• Danish Building Regulations 2018 (*BR18*) • The municipalities could until 2018 choose to oblige or not the connection to DH through the local heat planning (zoning)

Regarding heating, the **municipal utility company, Fjernvarme Fyn,** is the main actor, supplying almost all the demand in Odense and the neighbouring municipalities of Faaborg-Midtfyn, Nordfyn and Assens (51,700, 29,700, and 1,070 inhabitants respectively). As further explained in Section 6.3.4, this company is organised in 4 business units (BU): district heating distribution, waste incineration, energy production (CHP units and heat pumps), and energy services. The focus of this case study is the DH distribution BU.

DH is highly competitive in price. Its main competitor is individual heat pumps, with similar prices to DH but shorter lifespan (typically 15-18 years, while the DH grid has been operating for more than 90 years). As illustrated below, prices for individual natural gas (yellow) and oil solutions (red) are higher than DH (green), **mainly due to the environmental taxes in place in Denmark**.

Figure 2: Price competitiveness of DH (source: Fjernvarme Fyn)



6.3.3. Presentation of the DHC system

Fyn's district heating network is **among Denmark's largest**. Covering around **97% of the heating demand in Odense** and the surrounding areas, the DH supplies more than 70,000 customers, mainly one-family houses, along its 2,264 km distribution grid. A customer is normally a building owner, ranging from large multifamily buildings to one-family houses.

Figure 3: Key facts and figures of Odense DH network (2019)

Key facts and figures (2019)	
DH market share	97%
RES share	77 %
CO_2 emissions (heating)	87.1 kg/MWh
Installed Capacity	1 509 MW
Energy Production	2 083 GWh/y
Km network (double-pipe)	2 264 km

Operated since 1929 and firstly utilising the low-cost surplus heat from the local power plant, the DH grid has gradually developed. Since the approval of the Heat Supply Act of 1979, the development of the DH system has been boosted. During the last 10 years, it has experienced a stable **10% growth**, connecting around 600 new customers every year (1,600 in 2019). Since 2009, the grid also supplies **district cooling to a tertiary client**.

One of the key factors influencing the success of DH is the deployment of simple and low-cost substations. **Around 75% of the heat is sold to one-family houses** with an average consumption of 110 kWh/m^2/year. All **heat emitters are directly connected to the DH grid**, without heat exchangers or any mixing loop (which is made possible by the fact that all consumers have the same type of low temperature emitters as detailed below), which significantly reduces costs. Only hot tap water is heated in each building substation thanks to heat exchangers or hot water tanks to ensure high quality of the water to the consumers. Besides, the grid used mainly **mechanical flow meters** when they were cheaper than heat meters, and in 2014, when modern heat energy meters became cheaper due to mass production, all 67,000 mechanical flow meters were replaced with **modern electronic heat meters**, able to automatically transfer energy data to the operator.

The grid temperature level is low, which results in higher energy efficiency. The heat is supplied with circulating water at a pressure up to 25 bars and a **temperature between 60 and 90°C**. The **return temperature varies between 36 and 40°C.** All consumers have **low-temperature heat emitters**, as these have been largely deployed in Denmark to improve energy efficiency of both DHC systems and buildings and are required by the national Building Code since the 1990s.

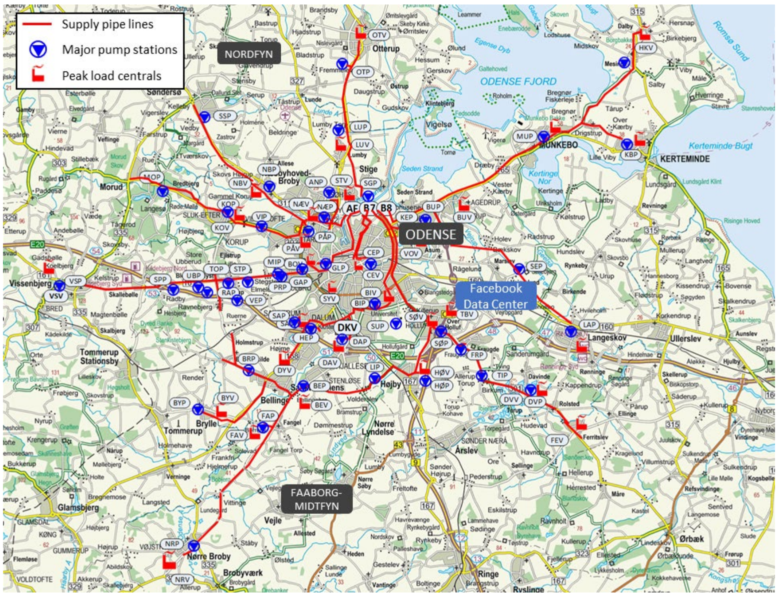


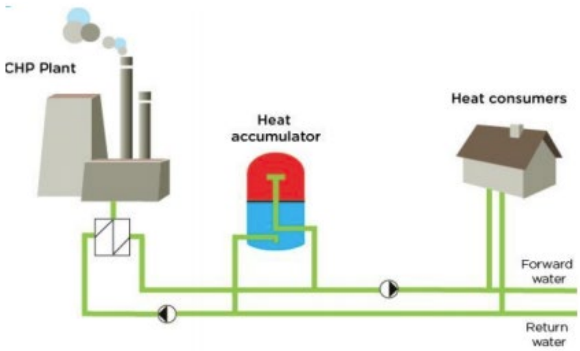
Figure 4: Fyn's distribution grid (source: Fjernvarme Fyn)

The heat production mix is mostly decarbonised, as depicted in Figure 6.

It is mainly based on **three CHP plants:**

- A highly efficient coal CHP unit[3] commissioned in 1990 – 488 MWth
- A waste incineration CHP unit supplying the DH since 1995 – 113 MWth
- A straw-fired CHP unit commissioned in 2009 – 85 MWth

Figure 5: Pressureless tank heat storage (source: Ramboll)



A 75,000 m³ **heat storage** pressureless tank with a storage capacity of **3,6 GWh** (e.g., 300 MW in 12 hours) and operating in direct connection with a maximum temperature of 95°C (90/40°C) helps maintaining the pressure of the DH network and enables the CHP plants to be operated in an optimal way. For instance, the large coal fuelled CHP plant can e.g. be operated in power-only mode during power peak hours.

[3] The coal CHP plant is one of the most efficient in the world, and was analysed in 2012 in the frame of a JRC report available on https://setis.ec.europa.eu/system/files/1.DHCpotentials.pdf

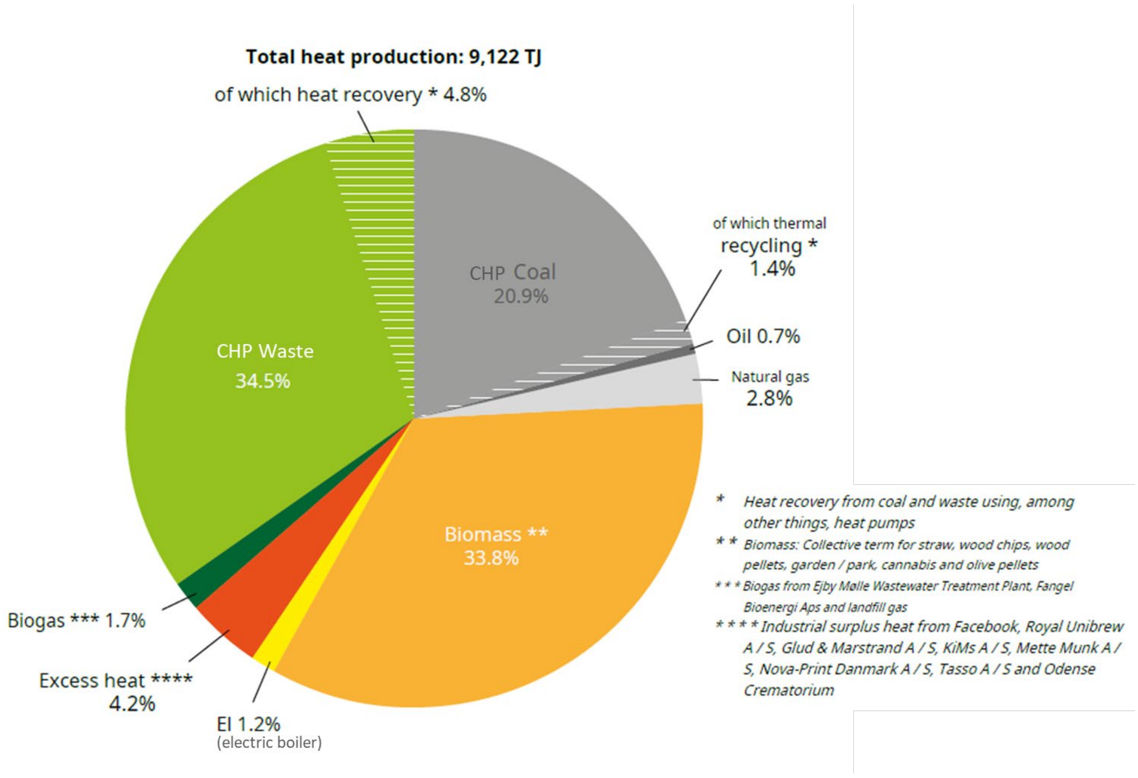


Figure 6: DH energy production mix in 2020 (source: Fjernvarme Fyn)

Since 2020 the DH system is also supplied by **heat pumps** used to recover excess heat from the waste incineration unit, wastewater, CHP plants and a data centre for a total installed capacity of 65 MW. The latter remarkable project recovers **waste heat from the Facebook data centre** located in Odense. The project figures among the world's largest waste heat recovery projects using heat pumps **with a total heating capacity of 44 MW**. It was conceived to replace most of the heat produced by the coal fire CHP as further described in 6.3.5.

The DH mix is completed by a **50 MW electric boiler** in operation since 2021 (a second 50 MW boiler will be commissioned this year as well), **woodchip fired plants and industrial waste heat** from all kinds of industries: paint production, breweries, etc. An additional 758 MW fuelled with natural gas (20 boilers), oil (41 boilers) and wood pellets (1 boiler) are installed throughout the DH network for **peak load** (red points on Figure 4).

In 2009, the network started supplying **district cooling** to a tertiary customer (IKEA) and plans to develop district cooling as a new business unit on commercial conditions, benefitting from the combined use of large heat pumps for district heating and cooling.

6.3.4. Governance and business model

Governance

Fjernvarme Fyn[4] is 97% owned by the municipality of Odense, and 3% by the North Funen municipality. As all DH companies in Denmark, its activities are regulated, and it operates under the principles stated in the Heat Supply Act (non-for-profit, DH zoning, etc.).

[4] https://www.fjernvarmefyn.dk/

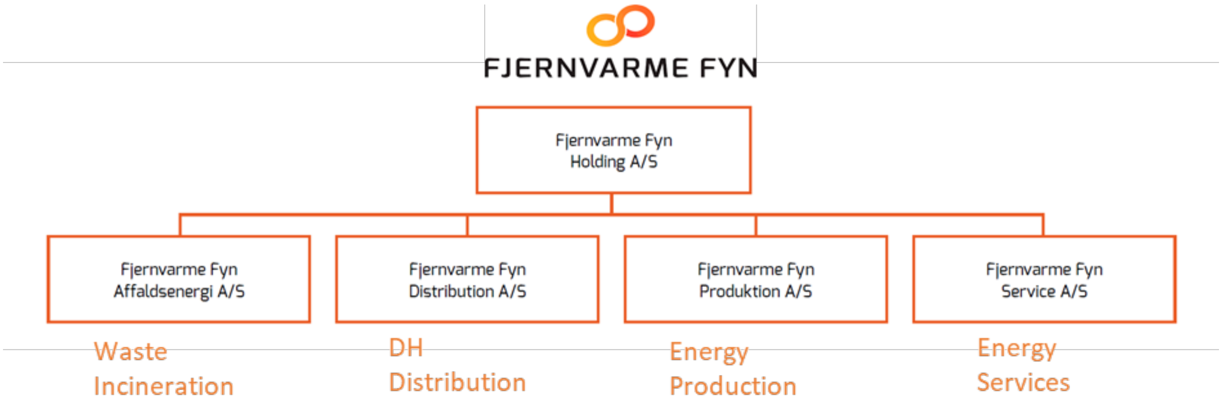


Figure 7: Legal structure of Fjernvarme Fyn (source: Fjernvarme Fyn)

Services provided include **district heating, domestic hot water supply and related services**, including the optimisation of secondary systems to increase energy efficiency and reduce the return temperatures, resulting in a lower tariff as explained hereafter. Energy efficiency advise is also offered to clients for free, mainly targeting a reduction of the return temperature.

Due to the non-for-profit principle under the Heat Supply Act, **all profit is transferred to the consumers, via tariff reductions and stable prices**. However, the DH network operates on commercial principles, aiming at providing customers with the **best possible heat supply at the cheapest price**, while contributing to an increased energy and **environmental awareness** among them. To pursue these objectives and remain the preferred heat supplier, a 5-year strategy with an associated action plan is in place since 2018.

The DH network is highly reliable (99.4% reliability)**, and one of the cheapest in the country.** This is the result of a combination of measures undertaken throughout the last decades, when the DH operator has managed to reach an adequate rhythm of investments from which one could highlight:

- The **reduction of heat losses and leaks** by replacing old pipes with pre-insulated ones, equipped with alarm wires to detect leaks;
- The **progressive diversification and modernisation of its production mix**, as presented above, to integrate the most relevant energy sources and technologies taking into account technical and economical criteria;
- The **direct connection** of one-family-houses, replacing heat exchanges with pressure reduction station and thereby improving the efficiency and providing clean make-up water to all consumers.

Disconnection from the grid is possible with 1 month notice, but not requested by clients.

DH Prices and Tariffs

The average annual **heat price** for a Danish standard house of 130 m^2 consuming 18.1 MWh/y is 1,750 EUR (13,000 DKK) which is among the 3 cheapest in the country.

The **DH tariff structure** in Odense has 5 components, reflecting the operator's costs:

- A **connection fee,** of around 3,360 EUR for one-family houses (25,000 DKK)
- Two **fixed parts,** representing around 20% of the annual bill:
  - A fixed annual meter fee (DKK/y)

  - An annual power contribution, depending on heated area (DKK/m^2/y)
- Two **variable parts,** representing around 80% of the annual bill:
  - **Energy consumption** (DKK/kWh) depending on the actual consumption;
  - **Water flow or "transport fee"** (DKK/m^3), depending on the amount of DH water circulating in the client's secondary system, and including a discount for big consumers. This tariff component encourages consumers to lower their return temperature (to reduce the water flow) and is therefore an **incentive for system's efficiency.** Figure 8 below illustrates the tariff impact of a poorly cooled secondary system (ΔT=14°C on the left) with respect to an adequately cooled one (ΔT=30°C on the right). The former tariff is 32% higher[5].

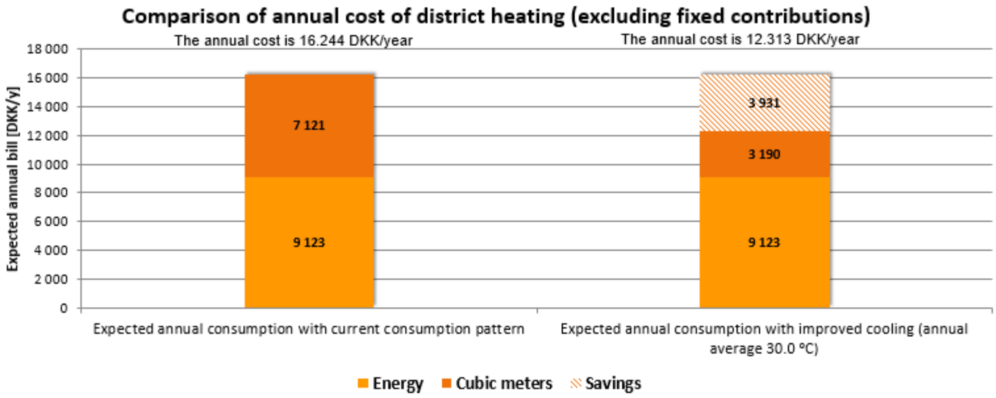


Figure 8: Impact of the return temperature on the variable part of the tariff (source: Fjernvarme Fyn)

Business model for waste heat recovery

As previously mentioned, the DH operator is **continuously looking for heating solutions allowing to reduce its costs**, including the recovery of waste heat from third parties, such as industries and businesses.

In Denmark any new large DH project requires a socio-economic assessment in the form of a heat planning study or "**project proposal**" based on a **20-year cost benefit analysis** (CBA) following a common methodology defined by the Danish Energy Agency comparing the project with a reference and an alternative scenario, and proving that it is the most cost-efficient from a socio-economic perspective. The project proposal has to be approved by the City Council, in charge of heat planning, before being implemented, and the approval can be appealed to Energy Appeal Board (*Energiklagenævnet*[6]).

The waste heat recovery from Facebook's **data centre** followed this procedure in 2019. This project, further explained in the following section, represented ca. **17.5 MEUR**[7] **total investments** (excl. VAT), undertaken mainly by Fjernvarme Fyn and to a lesser extent by Facebook (for the equipment in their buildings), and has a 25-year lifespan (a residual value is therefore considered in the CBA).

[5] Detailed calculation publicly available: https://www.fjernvarmefyn.dk/spar-paa-energien/overblik/faar-du-varme-nok-ud-af-dit-fjernvarmevand
[6] https://naevneneshus.dk/start-din-klage/energiklagenaevnet/om-naevnet/
[7] 130 million DKK (1 DKK = 0.13 EUR on 02/04/2021)

- Its **reference scenario** was the existing DH production, taking into account the expected coal phase out in 2025(as the study was undertaken before shifting this target to 2023), and a replacement of this production with large heat pumps and a smaller biomass CHP plant. Comparing the project to this reference, the project proposal demonstrates:
  - A socio-economic benefit of ca. 9.4 MEUR (70 MDKK) corresponding to **17% lower costs than the reference** scenario. The project mainly replaces heat from the coal fuelled CHP plant (91% of the waste heat production).
  - **28% energy efficiency** (in terms of final energy) compared to the reference.
  - **71% CO_2 emissions reduction,** representing a total saving of 151,888 ton CO_2eq.
  - A corporate **financial result for the DH company 20% higher**, with a net present value of 8.6 MEUR due to lower costs than the reference.

- The **alternative investment** would be to maintain the existing DH production until 2025, and then build a new biomass CHP plant. The project proposal shows a socio-economic benefit of ca. 6 MEUR (44 MDKK) corresponding to **12% lower costs** than this alternative scenario.

This study demonstrates the waste heat recovery project is both socio-economically and financially advantageous, and the associated sensitivity analysis shows that the project is also reasonably **robust**, being mainly sensitive to rising electricity prices.

6.3.5. Use of RES and waste heat

Fjernvarme Fyn is planning to **phase out the use of the 33-year-old coal fuelled CHP plant** in the production mix by 2023. It is a central focal point of the company's current strategy. It will be a major step in the ongoing process of converting the production of the district heating towards a decarbonised mix.

In 2019, the production mix was already reaching a **77% renewable ratio** thanks to local energy sources as depicted in Figure 6 above:

- 34% of the heat is generated by biomass facilities, including the straw-fired CHP plant using locally produced straw;
- 35% comes from the waste incineration CHP plant running with waste mainly from Odense;
- 8% from various renewable and waste energy sources, namely surplus heat, biogas from landfill, and renewable electricity (through the electric boiler and heat pumps).

To phase out coal, Fjernvarme Fyn is adopting a **wide range of both new and well-known climate friendly technologies, mainly valuing waste heat.** Since 2020 some solutions have already been implemented:

- 20+24 MW heat pumps converting surplus heat from the **Facebook data centre**;
- 6 MW heat pumps running with the surplus heat (flue gas condensation) from the **waste incineration CHP plant;**
- 19 MW heat pumps to recover heat from a **wastewater treatment plant** (WWTP)

- 10 MW heat pumps running with the surplus heat (flue gas condensation) from the **straw fired CHP unit.**

All these solutions are supplying the DH grid according to an order of priority based on cost-efficiency, as illustrated in the graph below: first waste incineration, then the straw fired unit followed by heat pumps and woodchips fired units. At last, the coal-fired CHP unit is prioritized over gas and oil-fired boilers.

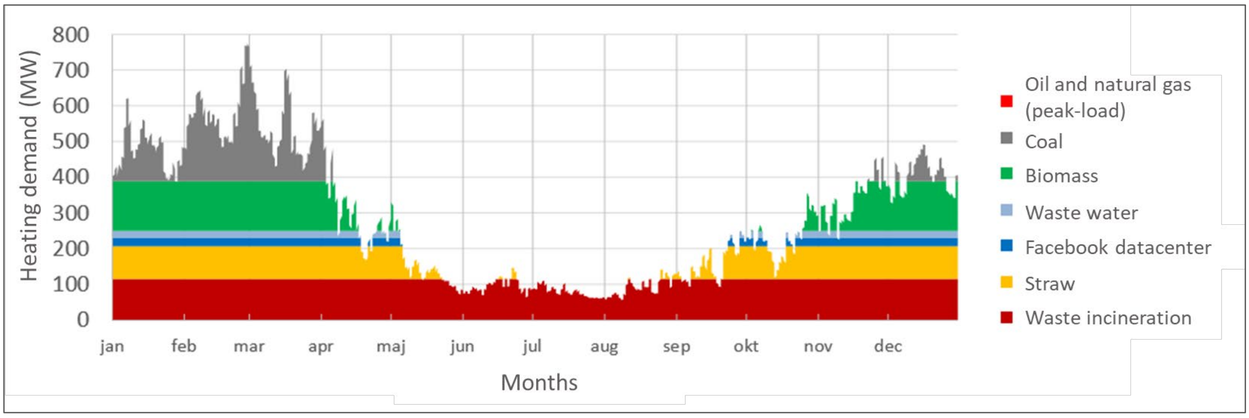


Figure 9: Heat production and priority order of the DH (source: Fjernvarme Fyn)

Recovering waste heat from Facebook's data centre

The project to recover waste heat from the Facebook data centre is game changing, as it had never been done before at such a large scale. After 6 to 7 years of planning with 3 years of negotiations, the project could emerge in two phases:

- A **first phase with 24 MW heat pumps** on the existing servers tested in 2019 and commissioned in 2020;
- A **second phase with 20 MW** more on other existing servers, also commissioned in 2020.

Figure 10: Facebook data centre and the heat-pump station (source: Ramboll)

The second phase was completed in August 2020. Since then, the heat pump station supplies around 10,000 households in a nearby residential area. Additional waste heat potential has been identified and could be integrated in the future (cf. Section 6.3.7).

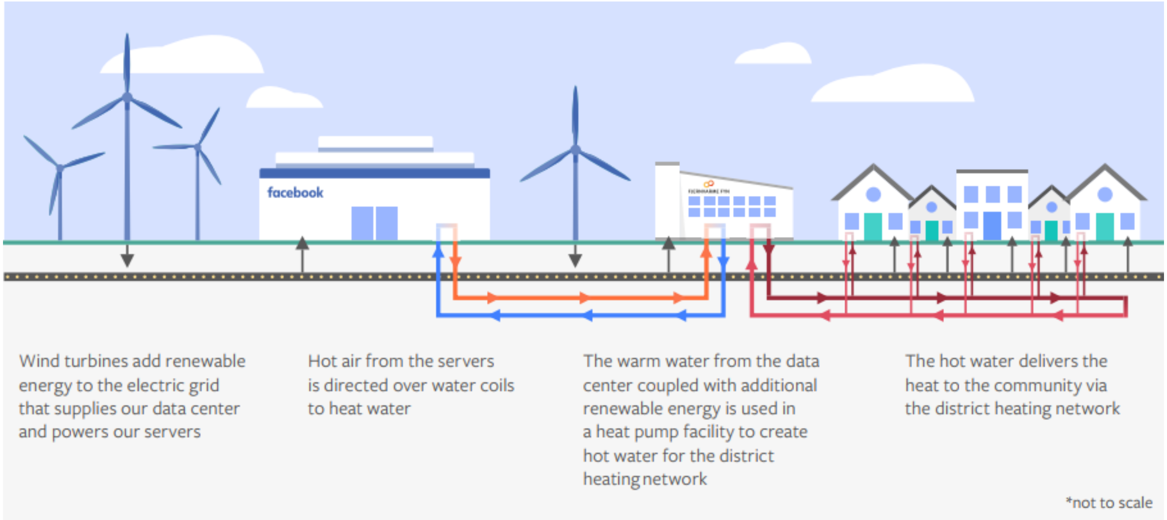


Figure 11: Heat recovery from Facebook data centre in Odense (source: Facebook)

Ammonia heat pumps were chosen to recover the heat produced by the air-cooled servers. The air heated by the servers is directed over water coils that recover the heat. This warm water recovered at **40°C** is then delivered to the heat pump station where the temperature is raised to **70°C** and delivered to the DH grid through another water circuit. The system has a **COP of 5**, higher than expected

The Facebook **waste heat recovery circuit** is chilled from 30-40°C to around 10°C thanks to the three parallel heat pumps groups, each of them containing three heat pumps in series. This system enables a flexible capacity of regulation between 10 to 100% of the total power installed.

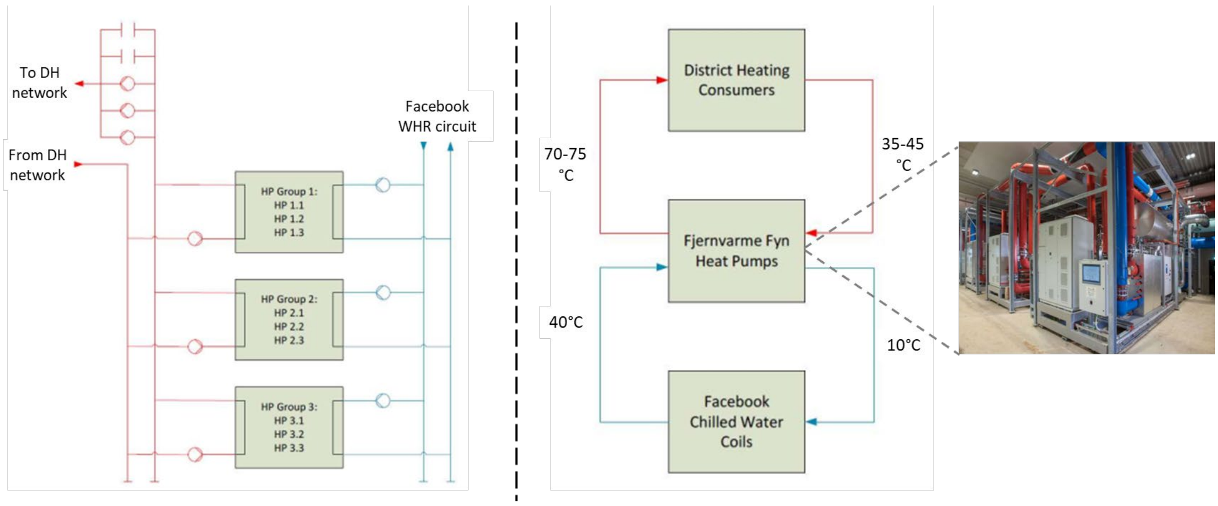


Figure 12: Waste heat recovery circuit and working temperatures (source: Ramboll)

6.3.6. Sector integration approaches and local value creation

Odense's DH network values several synergies between heating and other sectors, namely waste, wastewater, electricity, industry and data centres. The **waste heat** recovered thanks to the DH grid would probably remain untapped without it. Besides, the DH grid contributes to the integration of intermittent **renewable electricity**, as illustrated in below), and a higher electrification is expected in the future (cf. Section 6.3.7), contributing to the grid's decarbonisation strategy while enabling new balancing services to the electricity grid.

The **heat storage** tank, which was important for optimizing the operation of the CHP plants, will continue to play an important role in the future for optimizing the operation of the heat pumps with respect to the electricity prices, e.g., to be able to stop the heat pumps in power peak hours.

Fjernvarme Fyn contributes to the city's **building renovation strategy** by providing consumption data (current and historical consumptions over several years). It also **allows all consumers to track their consumption**, as meters' information is available through a mobile app and the DH website, in order to increase their awareness on consumption habits and encourage energy saving behaviours. Residential customers can track their daily consumptions while professional customers can also see demand per hour.

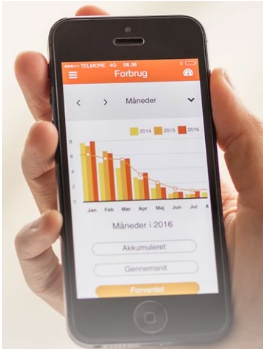


Figure 13: Consumption monitoring app (source: Fjernvarme Fyn)

The national project proposal procedure explained in Section 6.3.1 ensures all DH projects create **socio-economic value** (reduction of energy bills, energy efficiency, reduction of environmental impacts…). The municipal utility company employs 290 FTE, from which **42 FTE** working directly on DH and associated services. It contributes to the city's climate strategy, while ensuring a cost-efficient heat supply to consumers, where all the profit is transferred to them due to the non-for-profit principle ruling DH in Denmark.

6.3.7. Prospects

In the future, Fjernvarme Fyn is planning to integrate further surplus heat from local industries and its own production plants. It also expects to increase its district cooling sales, combining heating and cooling produced through large heat pumps.

In 2030, **electrical heat pumps are expected to play a significant role** in the DH energy mix as shown in the pie chart below.

To reenforce sector coupling and increase the share of renewables in the production mix, **seasonal heat storage** is planned for 2024, **coupled with electric boilers**. Two dam storages of 300,000 and 700,000 m^3 are currently being studied. They will enable synergies between large heat pumps, the existing thermal plants and two 50 MW electric boilers using renewable electricity to ensure peak load and to use **surplus electricity at zero prices** and thereby reduce curtailment of wind turbines (one boiler already in operation since 2021, and the second to be installed in the same year). The future concept of Fjernvarme Fyn's DH production is illustrated in Figure 15. As one can see, the large heat storage facilitates the link between the different production units, **strengthening the connection between the electricity sector and the DH grid**.

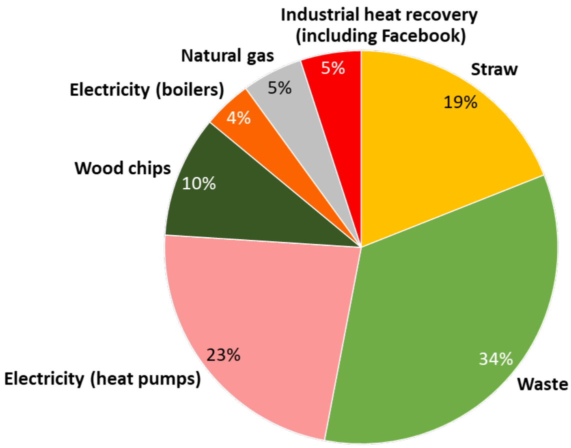


Figure 14: Expected energy sources for heat production in 2030 (source: Fjernvarme Fyn)

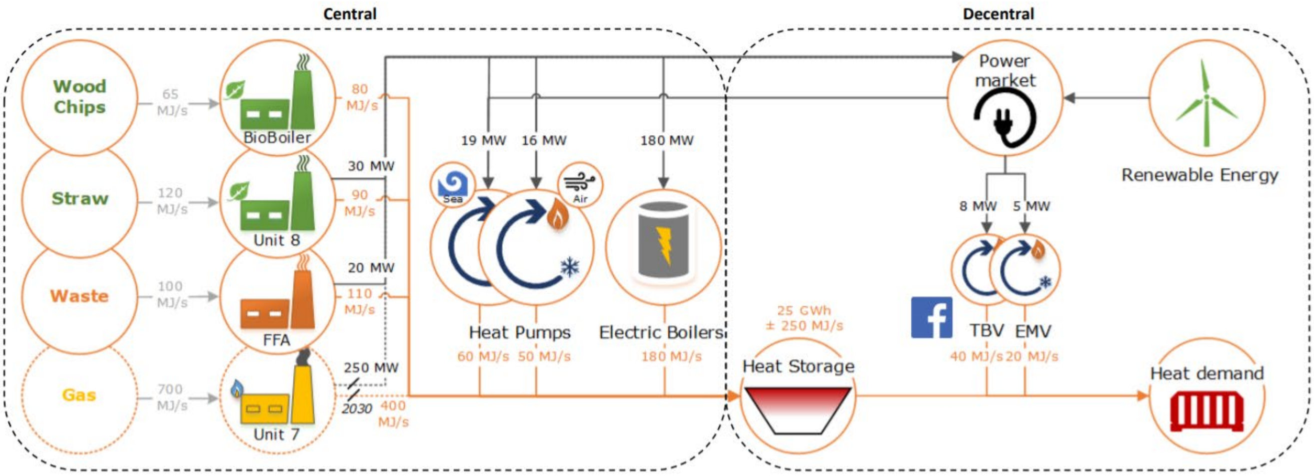


Figure 15: Future concept of Fyn DH production (source: Fjernvarme Fyn)

Detailed in the next figure, three scenarios of RES share in the power grid illustrate how the **DH coupled with heat storage and CHP will bring additional flexibility to the electricity sector,** and can provide balancing services to the electricity grid.

1) A high share of RES power in the electricity grid would lead to low electricity prices and the prior use of heat pumps and electric boilers in connection with heat storage to meet the heat demand and absorb the RES production.
2) In case of low RES, resulting also in higher electricity prices, CHP units are used for both heat and electricity production, constituting an additional source of revenue for the DH operator. However, the available production capacity provided by the **CHP** plants is **not subject to any capacity payment** in Denmark, which makes their future uncertain despite the demonstrated systemic value created.
3) At last, the system could also be self-sufficient in the case of moderate RES power thanks to the combined use of CHP, heat pumps and the heat storage.

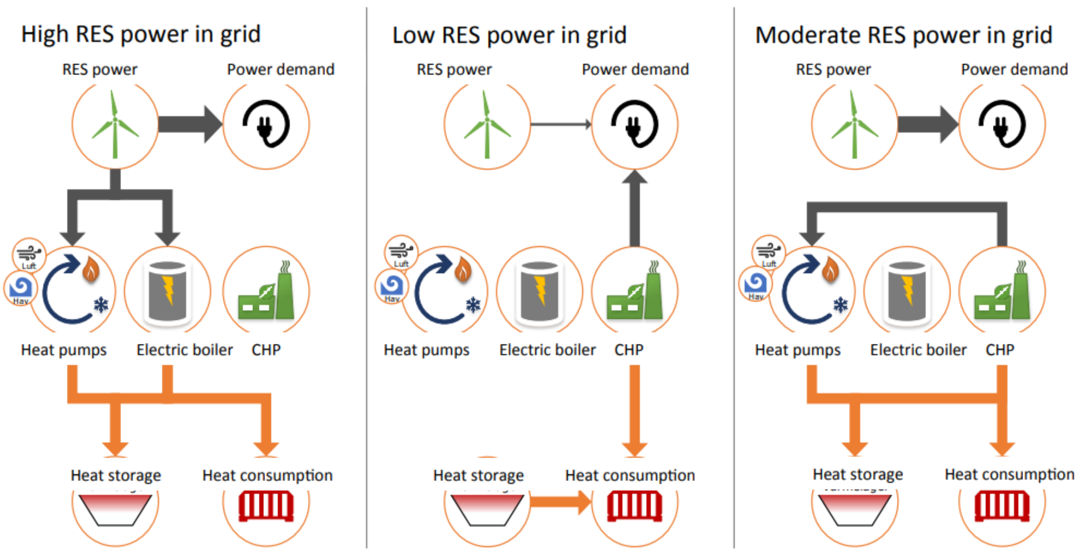


Figure 16: Operating modes depending on RES on the power grid (source: Fjernvarme Fyn)

6.3.8. Conclusion

The DH system of Odense illustrates how **decarbonisation and sector integration can support price competitiveness** in older networks, and showcases the potential of waste heat recovery from large data centres. The main key enablers for RES and waste heat integration identified are the following:

i. **The Danish regulatory and policy frame for efficient DHC**. The coherent package of policies and support schemes implemented since the 1980s have been the pillars of the deployment and progressive decarbonisation of DHC systems. Among others, this case study illustrates how this frame supported the price competitiveness of low-carbon DHC due to **environmental taxes** to fossil fuels and the mainstreaming of **heat planning** at local level, the impact of the non-for-profit principle in DH **governance**, and the importance of generalizing the deployment of **low-temperature heat emitters** (60/40 C) in buildings (by requirement of the national Building Code since the 1990s) to enhance the system's energy efficiency and to enable the integration of low-temperature waste energy sources. Besides, soft measures like the voluntary **national benchmark** of DH prices encourages price reductions.

ii. This national framework empowers cities and communities, reinforcing the **local energy governance.** Fjernvarme Fyn is 100% owned by the municipalities it supplies and contributes to their energy transition strategies. It promotes cooperation between **neighbouring communities** (1 network for 4 towns), and continuously seeks **synergies with other urban infrastructure** (electricity, wastewater, waste, data centres) **and local companies** (e.g., waste heat recovery from local industries). Through its tariff and by making consumption data available to all clients, **it fosters energy savings behaviours amongst consumers.**

iii. The **priority given to operational performance by the DH company's management** has also been essential to become the preferred heating solution. Fjernvarme Fyn has put **price competitiveness** and **quality of service** on the top of its agenda, and has a long-term vision supported by a mid-term strategy and action plans to become fossil-free while keeping prices low.

iv. The **renovation and modernisation strategy** in place for several decades, constantly seeking cost-effective improvements, is remarkable. Investments in modernising the heat pipes, production facilities and substations have been balanced, resulting in significant heat losses' reduction over the last 20 years (from 22% to 17%), and a mostly decarbonised production mix. The choice of **direct connection of one-family houses, without heat exchanges** or mixing loops, and the most cost-effective meters (initially mechanical flow meters, and since 2014 electronic heat meters), significantly reduced the system's costs and therefore also heat prices.

v. Regarding **production mix**, the DH company opted for diversifying its energy mix, integrating more and more **decentralised low-carbon energy sources** (i.e., RES and waste heat/cold sources), while integrating **complementary technologies**, such as heat pumps, electric boilers coupled with storage and CHP. This has also led to lower and stable prices.

vi. Finally, the DH company has proved to embrace **collaboration and innovation.** Flagship projects like the waste heat recovery from the Facebook data centre required both, and has become a world-class example for other data centres and DH networks. The recently implemented heat pump projects enabling to accelerate coal phase out, the direct connection scheme mentioned above, or the thermal storage project under development also illustrate the innovative approach of the DH system.

6.3.9. References

- 2021, Fjernvarme Fyn, Annual Report 2020
- 2021, Fjernvarme Fyn, Company presentation (by Jakob Storm Rasmussen)
- 2020, Ramboll, Waste heat recovery from data center - the technical facts
- 2020 Fjernvarme Fyn Annual Report
- 2019, Fjernvarme Fyn, Green transition of District Heating Perspectives from Fjernvarme Fyn (presentation of Kim Winther, Head of Business Development, Antwerpen, 11 December 2019)
- 2012, European Commission (JRC), Background Report on EU-27 District Heating and Cooling Potentials, Barriers, Best Practice and Measures of Promotion

6.4. Case study Greater Copenhagen (DK): progressive decarbonisation of a large DHC system through sector integration

6.4.1. National context

The national context for the Danish DHC sector has been summarised previously (cf. Section 6.3.1 Case study Odense).

The **trends** identified in this case study are in line with national ones, namely progressive decarbonisation of the production, higher sector integration and flexibility, evolution towards lower temperatures…However, due to its large size and integrated structure, briefly introduced in Sections A.2.1 and B.3.1 of the Main report of this study, and described in detail in other EU studies[8] [9], Greater Copenhagen's interconnected DHC system is unique.

6.4.2. Local context

The **urban context** of Greater Copenhagen's DHC system has been explained in Annex 5, where one could highlight the key role of municipalities as responsible authorities for **heat planning for collective supply** infrastructure (namely natural gas and district heating), based on a socio-economic long-term assessment of possible supply options. These municipalities are also in charge of **organising the replacement of gas boiler with district heating** (for larger consumers having a central gas boiler) **or heat pumps** (for one family houses and small consumers).

Table 3: Key urban indicators for Greater Copenhagen

		Greater Copenhagen
Statistics (2019)	Population (2020)	1 346 485
	Demographic trend (2015-2020)	+ 0.94 %/year
	Density (2020)	4 600 inhab./km²
	Housing (number of dwellings)	858 193
	Housing in multi-flats buildings	532 016
	Heating degree days	3 720
Regulation	Building and urban regulations	• Danish Building Regulations 2018 (*BR18*) • Heat planning done by municipalities • Zoning: The municipalities could until 2018 choose to oblige or not the connection to DH through the local heat planning

District heating is the main heating solution for the 21 municipalities supplied by Greater Copenhagen's DHC system, with **99% of market share** in the supplied districts. This is mainly the result of the national policies and regulations in place since the 1980s, such as the provisions within the Heat Supply Act, which have also shaped the ownership structure of the Danish DHC sector, and the environmental taxes.

[8] M. Galindo Fernández, C. Rogr-Lacan, U. Gährs, and V. Aumaitre, "Efficient district heating and cooling systems in the EU -Case studies analysis, replicable key success factors and potential policy implications," 2016
[9] M. Galindo Fernández, A. Bacquet, S. Bensadi, P. Morisot, and A. Oger, Integrating renewable and waste heat and cold sources into district heating and cooling systems Case studies analysis , replicable key success factors and potential policy implications External study performed by Tilia for the Joint Research Centre. 2021

DHC is also mostly decarbonised, contributing to Copenhagen's ambition to become the first carbon neutral capital by 2025. Initially based on fossil fuels, throughout its history the DHC system has gone through different decarbonisation phases that are presented in Section 6.4.5.

Both **DH and DC are currently growing**, replacing gas boilers and individual chillers.

6.4.3. Presentation of the DHC system

Greater Copenhagen is supplied by an interconnected DHC system including **2 transmission companies** (CTR[10] covering Copenhagen city and VEKS[11]), a large waste management and energy supply company (Vestforbrænding[12]), and **23 distribution companies** (the largest being HOFOR[13]), supplying more than 10,000 GWh/y of low-carbon heat to more than 1 million inhabitants.

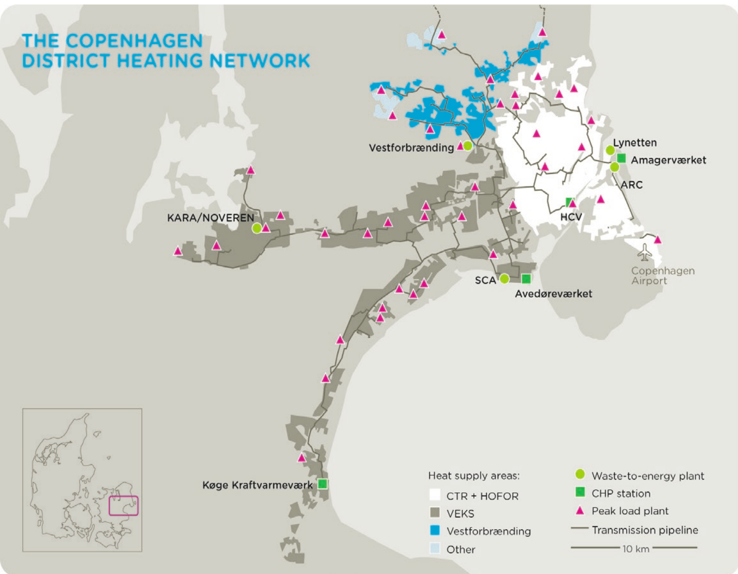


Figure 17: Map and key facts and figures of Greater Copenhagen DHC system (source: Ramboll)

Key facts and figures (2020)	
DH market share	99%
RES share	94 %
CO_2 emissions (heating)	80 kg/MWh
Installed Capacity	DH: 3,000 MW DC: 70 MW
Energy Production	DH: 10,800 GWh/y DC: 700 GWh/y
Km network (double-pipe)	DH: ~1,500 km DC: N.a.

The current **production** capacity and supplied energy per technology is as follows:

Technology breakdown (2018)	Installed capacity	Energy production (%)
Waste to energy CHP	~400 MW	30%
Biomass CHP	~900 MW	62%
Heat pumps, electric boilers	~200 MW	~0%*
Biomass boilers or CHP by-pass	~500 MW	2%
Peak boilers, gas, oil,	~1000 MW	6%
Heat storage (pressurized tanks coupled with CHP)	75,000 m^3	-
Cold storage (underground tank)	4,000 m^3	-

**Power-to-heat production is growing, and is expected to represent 17% in 2038, supported by national policies previously presented and the increasing competitiveness of these solutions*

[10] https://www.ctr.dk/
[11] https://www.veks.dk/
[12] https://www.vestfor.dk/
[13] https://www.hofor.dk/

6.4.4. Governance and business model

Governance

The **governance** of Greater Copenhagen's DHC system integrates numerous stakeholders that operate under the national framework previously mentioned, characterised by the "**non-for-profit" principle** which leads to continued improvements and the share of resulting benefits between the DHC operators and the consumers.

- The DH transmission companies and most of the distribution companies are owned by the **municipalities** they supply. One could thus consider they are indirectly owned by its citizens, which are also the DHC consumers.

- Among the distribution companies, there is also the largest **consumer-owned** DH company in Denmark, Høje Taastrup[14].

- Finally, a **State-owned** energy production company (Orsted[15]) and several **private producers** (CHP plant, heat pump plants…) are also connected to the DHC grid.

The objectives of these actors are shared with those of the municipalities, national government and consumers: supplying quality DHC services in a cost-efficient and sustainable manner, while ensuring security of supply and a clear long-term vision. To reach those objectives, all DH companies composing Greater Copenhagen's system are **progressively integrating RES and waste heat sources** in a cost-efficient manner (based on long-term cost-benefit analyses). **The expansion of the DH grid and the deployment of DC compensate energy efficiency measures.** According to the Heat Supply Act all investments in production plants have to be approved by the local municipality, proving they are more cost effective than the base case.

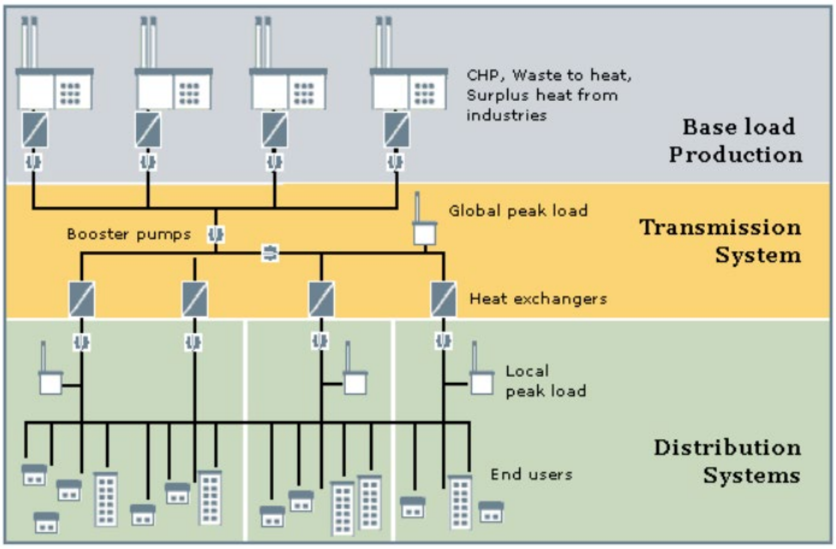


Figure 18: Functional scheme of Greater Copenhagen's DHC system (source: CTR)

[14] https://www.htf.dk/
[15] https://orsted.com/en/

The **unique structure** of this interconnected DHC system is the result of its historical development. The 2 **transmission companies** were created in the 1980s to implement waste-to-energy and CHP solutions, and transport the heat to the municipal and consumer-owned utilities, acting as DH distribution systems. They also provide peak capacity to the overall DHC system.

- **CTR** covers 5 municipalities including the city of Copenhagen, supplied by HOFOR, while **VEKS** covers the Western area (cf. Figure 21), supplying 12 municipalities. Both networks are directly interconnected, cooperate in a successful manner since their commissioning, and supply the different distribution grids, which complete their energy mix with their own local production.
- As large investments were needed for their development, the transmission companies were designed to take the minimum possible risks, for a better access to debt finance. To do so, a partnership with all the delivered municipalities was established, were these agreed to be supplied by the transmission companies and to be liable for the debt.
- HOFOR, VEKS and CTR operate all together the **heat dispatch unit**[16] in place since 2009, optimising the production of the different units of the overall DHC system taking into account electricity prices.
- **Vestforbrænding** is considered by some experts as a third transmission company. It owns a large waste fuelled CHP plant, a gas fuelled CCGT plant and an electric boiler, and distributes heat through its own network to 4 municipalities and one of the 5 municipalities who are mainly supplied from CTR. The remaining surplus heat from the waste fuelled CHP is transmitted to CTR and VEKS via heat exchangers. Thereby the heat load dispatch of Vestforbrænding operates in line with the heat dispatch unit.

DHC prices and strategies

In the long term, DH is the most cost-efficient heat supply solution in the DH zones of Greater Copenhagen, as demonstrated by the heat planning study (called "project procedure") required by the Heat Supply Act. All new investments in DH networks have to be approved by the local municipality and the decision criterion is cost-effectiveness for the society, including costs for the environment (i.e. externalities). **Price competitiveness and stabilisation is thus at the core of the DHC utilities' strategies.**

The DH prices for final consumers depend on the specific local situation of each municipality (production and distribution costs, efficiency of the networks, etc.), while **transmission companies' prices are the same for all** of their clients.

The tariffs are cost-reflective and encourage energy efficiency.

- For instance, **VEKS** tariffs include a fixed part (DKK/kW) based on 3-year past production, and since 2020 also a **variable part (DKK/MWh) changing on a monthly basis, providing a signal about real production costs** (higher in winter, very low in summer mainly due to available waste-to-energy production) and therefore encouraging smarter solutions (e.g., producing DC from this heat in summer, introducing thermal storage…). CTR follows a similar approach.

[16] Details on the heat dispatch unit available on: https://www.varmelast.dk/

- Most of the distribution companies have introduced a **tariff component encouraging lower return temperatures, to improve the efficiency of the overall system** and therefore reduce costs. This kind of incentive empowers consumers to take climate action, as the return temperature depends on them. For example, Høje Taastrup introduced in 2017 such a bonus-malus tariff, with a target return temperature at 43°C. For each °C above this target, clients must pay a penalty of 10 DKK/MWh, and if their return temperature is below this target they get a bonus of the same amount. As a result, **the average return temperature has been reduced by 1°C per year, proving the effectiveness** of such a tariff scheme[17].

6.4.5. Use of RES and waste heat

Greater Copenhagen's DHC system has been **progressively expanding and decarbonising its energy mix**. The key milestones of its transition from fossil fuels to the current mix, mostly decarbonised through a balanced mix of low-carbon energy sources, are summarised in Table 4, and was built on four main pillars.

Table 4: Key historical milestones in Greater Copenhagen's DHC production
(source: Ramboll)

1970 *Starting Point*	***2010*** *An interconnected system based on waste-to-energy and CHP*	***2021*** *Decarbonisation through sector integration, synergies with the electricity sector, lowering operating temperatures*
• Low share of DH • Mainly steam and **high temperature** systems • **100% oil**	• High share of DH at **lower temperature** • Interconnected DH system based on **waste-to-energy, coal and gas CHP** • Heat dispatch unit	• Steam system closed in 2021, lowering the operating temperatures and heat losses • From coal to biomass, **system mostly decarbonised** • More DC and **sector integration** (heat pumps, electric boilers, waste heat from water utilities and data centres, heat storage…)

1. Lowering the heat emitters' temperature

One of the key technical enablers of the integration of RES and waste heat sources in Copenhagen, and to the overall improvement of energy efficiency in both the DHC system and buildings, is the generalisation of **lower temperature heat emitters in all households.**

While heat emitters in the 1970-80s operated at optimal regimes for oil boilers (90/70°C), **the deployment of DH pushed the emitters' temperatures down**, for the sake of energy efficiency. In the 1990s, the Danish building code integrated for the first time a requirement for heat emitters to operate on 70/40°C regime, strengthened at a second stage to **60/40°C**. As a result, today buildings in Copenhagen have an average temperature regime of 75/50°C. **Thermal refurbishment programmes typically**

[17] Details on Høje Taastrup incitative tariff available on: https://www.htf.dk/returtemperatur-tarif

address also secondary systems and heat emitters, seeking at lowering return temperatures.

2. Upgrading the networks, converting steam systems to hot water

The DH network of Copenhagen dates back to 1903, and has gradually developped using heat from CHP plants. When the Danish government decided to develop a national energy efficiency and energy independence strategy after the 1973-74 oil crisis, supporting the development of DH and CHP plants across the country, one of the first measures consisted in **retrofitting the existing DH pipes** (e.g., replacing leaking concrete ducts with insulated pipes) to reduce heat losses and extend the lifespan of the system.

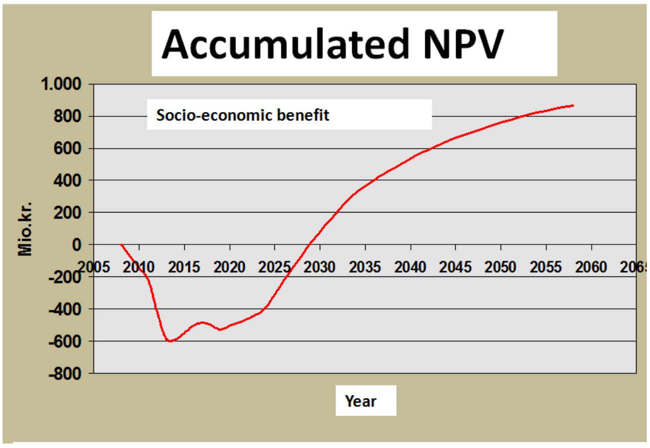


Figure 19: Socio-economic cost-benefit assessment of steam conversion in Central Copenhagen (source: HOFOR, 2017)

Besides, first generation DH systems in Copenhagen were based on **steam** and have been gradually converted to hot water since 2010. Those superheated steam systems were built to supply high temperature DH to energy intensive industries, which over the years moved outside the inner-city area. The operators of those systems, HOFOR and Frederiksberg, decided to **switch to water-based systems mainly to reduce heat losses and investments in new pipes.** In the case of HOFOR (central Copenhagen), this resulted in 4% reduction in the heat tariff and 200 MDKK savings, and allows to further integrate low-temperature RES**.** By decreasing the operating temperature, the efficiency of the production is also improved. Indeed, the heat losses in the new hot water network replacing the steam system is only 4%, whereas the losses in the steam system were 23%.

The **superheated network** (165°C) which was established by Vestforbrænding in 1975 to serve a hospital and industries has since 2000 started a **transition towards hot water system** below 110 °C. Today the maximal temperature is 125 °C in the old main transmission network, whereas all new networks established since 1980 are hot water systems below 110 °C.

3. Changing production technologies: towards higher share of RES and waste heat

While the first technology switch in Copenhagen's DH system consisted in replacing oil boilers with waste-to-energy and coal and gas CHP in the 1980s-90s, the DH system has gone through a **progressive decarbonisation** since then.

- CHP plants switching **from coal and gas to biomass** (wood chips, waste wood, straw and wood pellets). The last fossil CHP plant (using gas) is expected to close in 2021.
- Valuing **ambient energy** (e.g., wastewater) and **waste heat** from industries, wastewater facilities, data centres or tertiary buildings (e.g., vegetables and flower markets in Høje Taastrup) through heat pumps.
- Valuing synergies with the electricity system, namely the possibility to use **renewable electricity** through heat pumps and electric boilers, but also to store it through thermal storage and to provide **balancing services to the power grid.** CHP plants also contribute to the electricity grid stability, as they

are operated in an optimal way with large heat storage tanks and sea water cooling in case of large electricity prices and excess capacity.

Indeed, electric boilers are being used to avoid wind curtailment and to down-regulate the power system, and DHC control rooms can **take into account electricity price signals to optimise the production**, as illustrated in Figure 20. DH systems can thus produce heat through thermo-electrical equipment when electricity prices are low, usually due to high share of intermittent renewables on the power grid, and produce electricity through the CHP plants when prices are high or up-regulation is needed.

The recent **reduction of electricity taxes for comfort heating and cooling** (2020) will facilitate further synergies between the heating and electricity sectors.

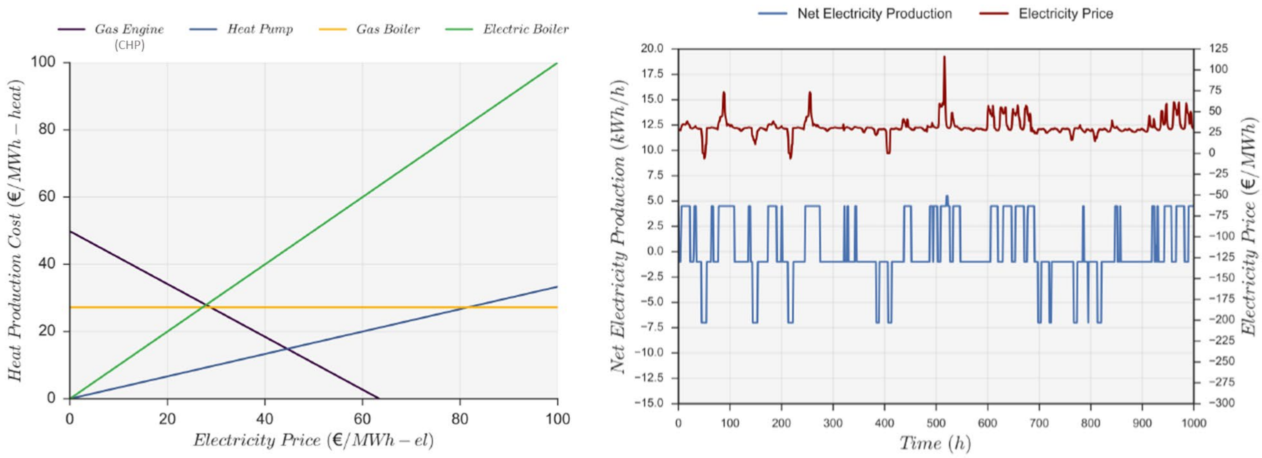


Figure 20: System response on fluctuating electricity prices (source: Ramboll)

- Finally, some of the newest production facilities in Greater Copenhagen combine the features above, such as ARC[18]'s **new waste incinerator CHP** (built in 2019, with a capacity of 70 t/h), which uses latest technologies, integrates flue gas condensation (i.e., **waste heat recovery**) and a **turbine by-pass (equal to an electric boiler)**, showcasing 107% efficiency. Indeed, all new CHP plants are with turbine by-pass allowing them to avoid power production in case of zero or negative prices, and to integrate intermittent electricity production (mainly wind), bringing **flexibility to the electricity system**. In particular the new large CHP plant Amager 4[19], fuelled by waste wood, has the ability to operate from maximal power generation without flue gas condensation to zero power generation, maximal heat generation with flue gas condensation and turbine by-pass.

  It is also planned to establish **carbon capture facilities** at all the waste incinerators and the largest biomass CHP plants which have long utilization times, probably before 2030, and to use the surplus heat from the process. The first test plant at ARC is being constructed at thetime of writing this report. The plan is to follow up with **electrolysis** and generate hydrogen, which can be combined with the captured CO_2, as well as useful heat for the district heating.

[18] https://a-r-c.dk/
[19] https://www.hofor.dk/baeredygtige-byer/amagervaerket/bio4-projektet/visionen-for-bio4/

4. <u>Integrating heat storage and district cooling</u>

Thermal storage and district cooling are also key enablers for the city's climate neutrality in heating and cooling.

- **Thermal storage** has been developed in Copenhagen for several decades to optimise the operation of CHP plants. It currently continues to be developed as a means **to optimise the whole DHC system** taking into account electricity prices (coupled with large heat pumps and electric boilers). Besides, Aquifer Thermal Energy Storage (ATES) can provide seasonal storage and significantly **increase the COP** (e.g., once integrated in the DHC system of Taarnby[20] using reversible heat pumps, the COP is expected to increase from 3.4 to 5.6). Thermal storage is therefore also a facilitator for a higher integration of intermittent renewables.

- **District cooling is rapidly growing**, with more than 10 DC clusters, most of them with **combined heating and cooling produced by heat pumps**, reaching **COP above 5**. It is expected that DC will gradually replace individual chillers with heat pumps and ATES, maximising synergies between DH and DC.

Figure 21: DHC production facilities in Greater Copenhagen (source: Ramboll)

6.4.6. Sector integration approaches and local value creation

Copenhagen DHC system is a recognised flagship example of smart sector integration. **The integrated (systemic) approach to energy planning in Greater Copenhagen has allowed to value numerous synergies with DHC**: DH-DC, waste management, waste heat recovery, free cooling (from ambient energy), synergies with water infrastructure and with the smart city strategy (notably by building a smart energy system), providing balancing services to the electricity grid...

[20] Further details on Taarnby DC project available on

Each DHC investment has to prove to be the best option from a socio-economic perspective during the planning phase ("project procedure"), and **the benefits to users and to the society as a whole are quantified and made publicly available** by the municipalities.

Consumers are key stakeholders in the DHC system and **own most of the facilities in a direct or indirect manner** (the latter through the municipal utilities). Most of the DHC utilities have installed remote heat meters and make **consumption data available** to consumers. Besides, their tariffs often include **incentives to reduce return temperature** and free of charge advise to do so, as illustrated above with the case of Høje Taastrup.

6.4.7. Prospects

The future of DHC in Greater Copenhagen will be shaped by the climate commitment of the metropolitan area to become climate neutral by 2025.

- A **transition from natural gas to DH or heat pumps** is needed to reach those targets. New heat planning studies and project proposals for substantial extension of the district heating networks are ongoing, steered by municipalities, to decide the optimal technology for each area previously supplied by natural gas. Subsidy programmes are also in place to encourage the switch from gas boilers to DH or individual heat pumps outside the approved DH zones.

- A trend towards higher sector integration is expected, including a high deployment of **large heat pumps coupled with storage** (estimated by some local experts at additional 400MW and 2 million m^3 thermal storage in the coming 20 years), and the deployment of **electric boilers** (additional 800 MW in the same period). DHC will therefore contribute to a higher integration of intermittent renewable electricity and provide more balancing services to the power grid. This will also contribute to **higher DC uptake.**

- Finally, a number of ongoing projects are studying the possibility of **capturing CO_2 from waste incinerators to produce methane** through hydrogenation (methanation). **Waste heat from electrolysers** is also seen as a potential source of energy for DHC in the future.

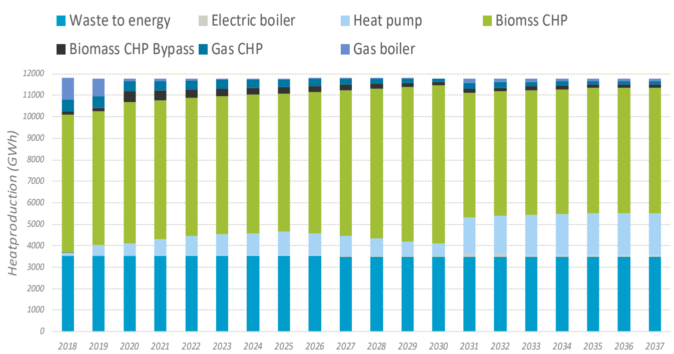


Figure 22: Expected production mix evolution for the DHC system (source: Ramboll)

6.4.8. Conclusion

The historical development of Greater Copenhagen's DHC system illustrates the **progressive decarbonisation of a large DHC system through sector integration**. The technologies as well as the cooperative and integrated approach that enabled this transition are highly replicable.

The key enablers for RES and waste heat integration identified in this case study are:

i. **The Danish regulatory and policy frame for efficient DHC** (cf. Section 6.3.1 – case study Odense). Danish policies and regulations have been supporting efficient DHC since the 1980s and have proved to be effective and efficient in decarbonising the heating sector. These are now focusing on encouraging higher sector integration and electrification (e.g., by removing electricity taxes for large heat pumps). This framework has also resulted in a very high level of **transparency on heat decision-making.** Added to this, **national benchmarks** on DH prices (among other public services) incentivise utilities to perform better and reduce their costs, ultimately resulting in lower prices for consumers.

ii. **A collaborative and open governance model**. The Danish DHC model is based on cooperation between all parties (utilities, consumers, municipalities, production facilities including waste heat suppliers, national authorities…). **DH utilities share benefits with consumers** through heat tariff reductions and contribute to local and national climate goals. Despite the strong sector regulation, they have proved to be **highly innovative and successful in establishing partnerships** with other public and private actors to reach their targets.

iii. **Low-temperature heat emitters** have been key technical enablers for improving the energy system's overall energy efficiency, and for integrating low-temperature RES and waste heat. **The deployment of DH pushed the heat emitters' temperatures down** from optimal regimes for oil boilers (90/70°C) to optimal levels for efficient DH (60/40), resulting in enhanced energy efficiencies at building and DHC network levels.

iv. All historical developments have been based on an **integrated system approach. Interconnecting networks** and coordinating their heat and electricity production through the **heat dispatch unit** enabled new synergies to be valued, and a higher uptake of low-carbon energy sources at the lowest cost. The **comprehensive methodology developed for local heat planning**, applied all across the country also for cooling in DHC grids, contributes to the overall coherence of the DHC developments. It ensures all DHC investments are made based on a **long-term socio-economic assessment of the different technical options**, valuing synergies between technologies, sectors, and actors.

v. **The retained model empowers consumers**. They are direct or indirect owners of the DHC networks and are well informed about their own consumption and strategic decisions. Thanks to the **incentive and cost-reflective tariffs** and free of charge advise from their local utilities, they are encouraged to reduce their return temperature, and to consume less when production costs are higher, becoming front-line actors of the system's energy efficiency.

vi. Finally, it is worth highlighting the **continuous efforts done by all DHC operators to identify and undertake improvement measures and to value all sustainable local energy sources**, and their highly innovative culture, both technical and organisational (heat dispatch unit, customer empowerment measures…).

6.4.9. References

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6.5. Case study of Helsingborg (SE): EVITA interconnector

6.5.1. National context

Sweden is the European leader in using renewable energy sources in heating and cooling[21]. It has put in place numerous **national policy tools** supporting this goal, such as fossil fuel taxes, a carbon tax for sectors not eligible to the EU Emission Trading System (ETS), the Electricity Certificate Scheme to develop CHP plants, and other environmental taxes. Besides, the national target of becoming **climate neutral by 2045** has been applied to all sectors, and the use of low-carbon energy sources in district heating and cooling is an essential part of this strategy.

Table 5: Key facts for DHC in Sweden

DHC in Sweden - Key facts		
Regulation	Regulator / Supervision authority	• DHC is not a regulated activity in Sweden • Other authorities: Swedish Competition Authority (*Konkurrensverket*): safeguards competition and supervises procurement
	Role of municipalities	• Most municipalities own their public utilities • Influence strategies to align with climate goals
	Ownership (in terms of sales, 2019)	• 65% Municipality owned heat supply companies • 35% Others (private or state owned heat supply companies)
Incentives	DHC support schemes	• Environmental taxes • District Heating Act (2008) aiming at protecting consumers and increasing transparency in the DH sector. Amended in 2011 to integrate further requirements in metering and billing (communication of monthly consumption) • DHC support available for investments in small scale DHC systems below 20 MW installed capacity « *Klimatklivet* » (outside EU ETS) • The Electricity Certificate Scheme to develop CHP plants
Market	Total DH sales to customers (2018)	• Heating: 50 951 GWh (50% of the total heat market) • Cooling: 1 156 MWh
	Main clients (in terms of sales, 2018)	• 60% residential, 28% tertiary, 12% industrial
	Main operators (in terms of turnover, 2017)	• Main private: Fortum (co-owner of Stockholm exergi), Vattenfall, E.ON, Solör Bioenergi, Värmevärden, Adven

The EVITA interconnector case study is an excellent illustration of **the current tendency of Swedish DHC systems to interconnect with their neighbouring grids**. It highlights a strong cooperation between three public companies who chose to interconnect their DH networks and, by doing this, enabled an overall optimisation of the networks and a higher valorisation of waste heat and renewable sources, in line with national and local climate policies.

6.5.2. Local context

This case study builds on Helsingborg's experience to analyse the **collaboration** between **three municipal energy companies operating district heating in different cities** that decided to connect their grids through the **EVITA** interconnector. Each of those companies sells district heating among other energy products like electricity and services about energy management:

- Öresundskraft is operating in **Helsingborg** (around 140 500 inhabitants in 2016)
- Landskrona Energi in **Landskrona** (around 32 500 inhabitants in 2016)

[21] 65% RES in gross final energy consumption in 2018, according to Eurostat

- Kraftringen in **Lund, Eslöv and Lomma** (around 121 000 inhabitants in total in 2016)

Table 6: Key urban indicators for Helsingborg

	Helsingborg City	
Statistics (2019)	Population	147 734
	Demographic trend (2015-2019)	+1.74 %/yr.
	Density	423.8 inhab./km²
	Housing (number of dwellings)	70 808*
	Housing in multi-flats buildings	45 218 (64%)*
	Heating degree days	3,034
Regulation	Building regulation (national)	• National energy performance standard (2017) • New building standard favouring DH over electricity is planned for 2020

**https://www.statistikdatabasen.scb.se*

In the case of **Helsingborg**, Öresundskraft was created in 1964 and knew a constant growth during the first 30 years. It has been stable for the last 10 years and now represents **80% of the heating market share**. New connections add up to energy savings/efficiency from older buildings, hence representing a **stable total demand**. The main alternative to DH is heat pumps, both solutions having a similar energy price level (variable costs). However, DH presents a lower connection fee than the heat pumps' CAPEX (around 2.5-3 times lower), and provides a better **price stability and visibility** on future prices, thanks to the voluntary adherence of Öresundskraft to the national initiative "Price Dialogue"[22] (explained in Section 6.5.4).

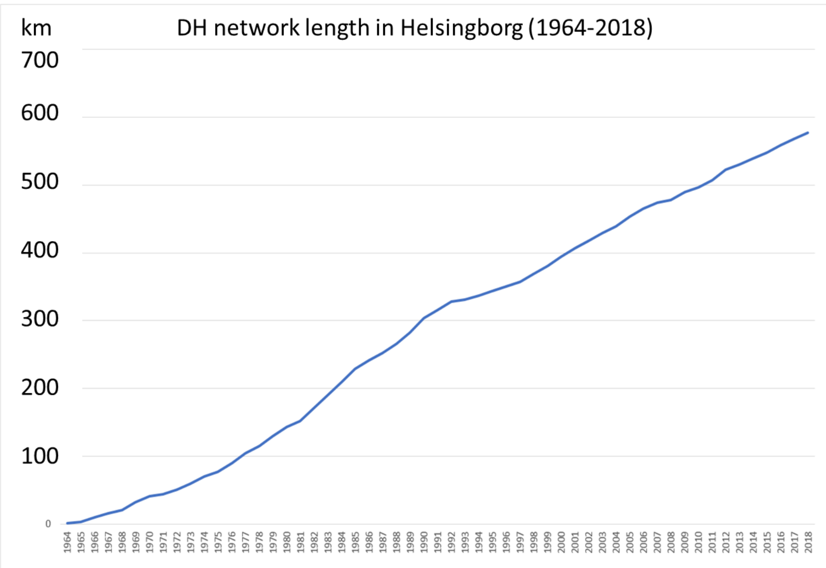


Figure 23: DH network length in Helsingborg (1964-2018) – Source: Öresundskraft

[22] http://www.prisdialogen.se/

Öresundskraft is 100% owned by the municipality of Helsingborg. As the city has set a Climate and Energy Plan[23] to become **carbon neutral in 2035**, there is a strong interest in further decarbonizing its DH system, through larger integration of RES and waste heat sources and Carbon Capture and Storage (CCS), for instance. Furthermore, public ownership entails a deeper understanding of long-term investment plans and depreciations needs, **accepting longer payback times** for some strategic infrastructure such as DH.

In Helsingborg, like elsewhere in Sweden, the heat market is completely liberalized and it is not mandatory for new buildings to connect to the DH grid. However, **municipal incentives to connect to DH exist in the new districts developed by the city**, as the connection is included in the price of land.

6.5.3. Presentation of the EVITA interconnection

The EVITA collaboration was created to connect the district heating network of Helsingborg with the networks of Landskrona and Lund, as illustrated in Figure 24.

The total length of the connecting pipes between the cities is 90 km and the **total heating demand is 2,3 TWh/y** :

- 1040 GWh in Helsingborg,
- 300 GWh in Landskrona and
- 1000 GWh in Lund, Eslöv and Lomma.

Table 7: Key facts and figures Helsingborg network (2019)

Key facts and figures	
DHC market share	DH: 80 % of the area covered
RES and waste heat share	100 %
CO_2 emissions (heating)	48 kg/MWh
Installed capacity	DH: 320 MW EVITA pipe: 60 MW
Energy production	DH: 1.04 TWh/y
Km network (double-pipe)	DH: 570 km EVITA pipe: 30 km

A **first discussion in 2005** between the energy companies of Helsingborg and Landskrona launched the idea of a connection between the two cities **to facilitate the third party access and to create a new lever for system optimisation**. After 4 years of studies, another 4 for discussions and negotiations integrating of the third partner Kraftringen, and 2 years of engineering and construction, the Evita collaboration resulted in the creation of a **DN500 district heating pipe of 30 km between Landskrona and Eslöv in 2015**, enabling energy transfer in both directions based on production costs.

Indeed, **the Evita connection aims to minimise each party's variable production costs** by linking the 3 DH networks. This allows to import and export district heating between the parties and achieve **optimal production throughout the whole system.**

[23] Climate and Energy Plan for Helsingborg 2018-2024 available on this link (only in Swedish)

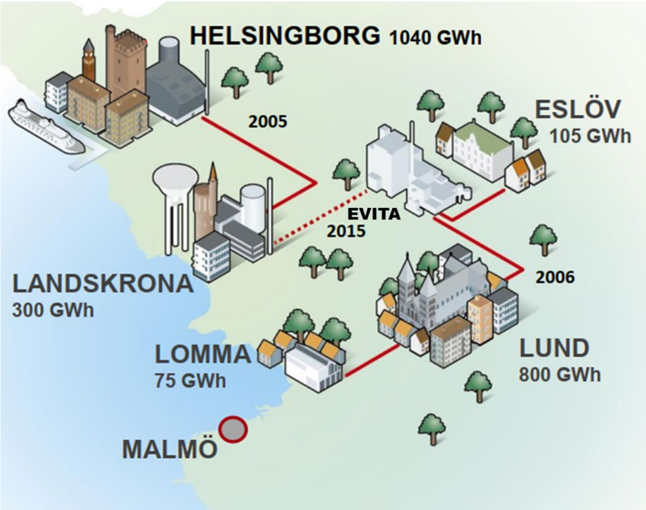


Figure 24: Grid and interconnection scheme of Helsingborg and surrounding cities - Source: Öresundskraft

Heat production is determined by the plant with the lowest production cost at each point in time (real time). As a result of the connection, the **production has shifted to the most efficient** production plants:

- Filbornaverket in Helsingborg, a waste-to-energy plant (73 MW heat)
- Energiknuten in Landskrona, a CHP plant fuelled by Refuse-Derived Fuel (RDF) (25 MW heat)
- Örtoftaverket in Lund, a biomass plant using recovered waste wood (100 MW heat)

The 3 interconnected DH companies import and export energy through the Evita interconnector, Helsingborg being the largest exporter. From Helsingborg's DH grid point of view, in 2018, 47 GWh were imported from the Evita connection and 135 GWh exported to other cities as illustrated bellow.

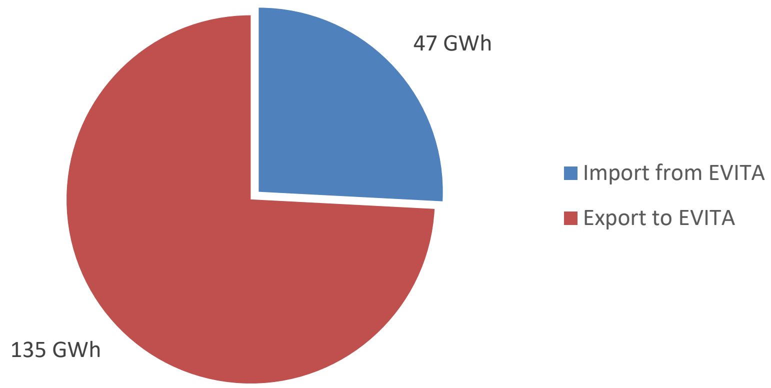


Figure 25: Energy transfer in 2018 between Helsingborg and the Evita connection (Source: Öresundskraft)

Along with the fact that the DH has become fossil fuel free, **the EVITA connection has contributed to reaching a low CO_2 emission ratio in Helsingborg**. It was considered to be around 48 g/kWh in 2019 because of plastic contained in waste. The main environmental benefit of the interconnector remains the higher integration of RES and waste heat in each of the interconnected DH grids.

6.5.4. Governance and business model

The **ownership of the district heating pipe created by the Evita collaboration** is shared by the 3 municipal utilities interconnected:

- 30 % is owned by Öresundskraft (Helsingborg)
- 20% by Landskrona Energi
- 50% by Kraftringen (Lund)

The governance and operational aspects of the interconnector are explained in a long-term **collaboration agreement** between these 3 parties, indicating also ownership and repartition of costs and benefits. This agreement has a **25-year** duration and includes automatic 5-year extensions if none of the parties terminates it.

Business model of the interconnector

The business model of the interconnector is based on transparency and open collaboration for a **common goal of better environmental and economic performance of the utilities**. By joining their efforts and resources, the 3 municipal DH operators become stronger:

- they benefit from **economies of scale** for their fuel purchases and **co-investment** opportunities,
- enable the integration of a **higher share of low-carbon sources**,
- improve their **security of supply**,
- **optimise the overall production**, resulting also in **more stable prices,**
- **share human resources** and **best practices**.

The **total investment cost of the Evita interconnector** was **31.3 MEUR** (320 MSEK[24]), shared between the 3 utilities in the same proportion as their ownership, **without any investment subsidy**. It was co-financed through the utilities' investment budgets, without the need of a project - specific debt funding.

- **Net income** within the Evita collaboration scheme (i.e., revenues minus direct O&M costs) is shared among the 3 parties based on the ownership ratio. Revenues consist actually on cost reduction thanks to the interconnector, calculated by comparing actual costs to a reference case without it using a simulation software, as further explained in Section 6.5.5.
- Regarding **costs**, each party is fully compensated for its direct and a portion of its indirect costs related to its exported district heating, the latter referring for instance to maintenance, taxes, or fixed fees.
- This model of cost and revenue sharing was preferred by the 3 neighbouring grids, instead of fixing a price for the exported heat.

As a result of the Evita collaboration, **the variable production costs have been reduced by an average of 1% (2.45 MEUR/y** or 25 MSEK), due to a higher use of waste-to-energy and solid recovered fuel, which is cheaper than woodchips and waste wood. This led to a robust business case for the Evita interconnection project with a payback time of around 14 years.

[24] 1 EUR = 10.22 SEK (exchange rate on 20/11/2020)

Figure 26: Evita interconnector DN500 pipes (pictures from the construction works by Mr Jan Lindeberg)

Negotiating Third Party Access

As previously indicated, one of the Evita collaboration's trigger was to **facilitate third party access** (TPA) to the 3 networks, in particular to waste heat and RES suppliers, provided it's technically and economically viable**.**

This is also an important element of Öresundskraft's strategy. In particular, the company is **continuously seeking for new opportunities to integrate waste heat sources.** As a result, numerous opportunities have been analysed, some identified by the utility and others proposed by potential waste heat providers. When exploring these opportunities, **joint feasibility studies** can be carried out either by the DH operator or by an external firm, depending on the capacities involved.

TPA is based on **bilateral negotiations**. In practice, open discussions are held between both parties, and price setting is generally **based on alternative production sources** for the DH operator, which shares with the third party its variable costs for heat production to enable a better understanding (e.g. heat production is cheaper in summer), which facilitates to reach an agreement on the waste heat price. In general, the agreement is based on a rule on how to **share the benefits between DH operator and the third party** (e.g. 50% each), **depending on how the risks are shared** (e.g. if there is only one party or if both parties bear the investment for the connection to the grid and the substation). Most of the TPA agreements in place are **long-term** (e.g., a chemistry industry has provided waste heat to Helsingborg's grid since more than 40 years).

Helsingborg's Prices and Tariffs

Each of the interconnected DH grids has its own tariff. In 2018, the average DH price in Helsingborg for a typical multi-family residential building was 81.5 EUR/MWh including VAT (833 SEK /MWh). Excluding VAT, this is 65.2 EUR/MWh (666 SEK). **The city of Helsingborg, owner of the utility, has capped the DH price** taking into account Sweden's average DH price, to ensure affordability.

Öresundskraft's offer includes also a **"DH Gold" option**, where the environmental impact of the consumption, namely the 48 g/kWh, is compensated by verified reduction in emissions in other countries. This costs an extra 0,02 SEK/KWh. In general, this option is mainly retained for large asset managers, owning many buildings and trying to reduce their environmental footprint.

While the Evita interconnector has not significantly impacted the DH price, it allows to ensure **price stability** in the long term.

The **DH tariff structure** in Helsingborg has 3 or 4 components, depending on the type of client:

1. A **connection fee;**
2. A **fixed part** (SEK/kW/y), representing 22% of the annual sales for residential clients and 20% for tertiary clients. This component is not impacted by the interconnector;
3. One or several **variable parts**, depending on:
    - **Energy consumption** (SEK/kWh) represents 78% of sales for residential clients, and 72 % for tertiary clients. Three **seasonal tariffs** have been set to reflect the utility's production costs (high in Winter, low in Summer, and medium in Spring and Autumn);
    - **Water flow** (SEK/m^3), only for tertiary clients (representing 8% of annual sales).

Prisdialogen
Mellan kunder och fjärrvärmeföretag

The evolution of DH prices in Helsingborg is agreed with consumers in the frame of the national initiative called **Price Dialogue** (*Prisdialogen* in Swedish). Helsingborg was indeed one of the first cities to join this **voluntary** initiative, launched in 2011 to **strengthen the customer's position to achieve a reasonable, predictable and stable price change** for DH and to contribute to increased confidence in DH suppliers' pricing. Throughout the Price Dialogue process, the utility discusses with **representatives of household and tertiary clients** to agree on a price increase forecast for 2 to 3 years (e.g., capping to 2-3% the increase in DH prices in this period). This procedure enables also discussions about various issues concerning DH like maintenance or fuel costs and gives consumers the possibility to comment on the utility's hypotheses and to participate in the price negotiation.

6.5.5. Use of RES and Waste Heat

The **energy transition in Helsingborg's DH network has been supported by the national policies and regulations** mentioned in Section 6.5.1, especially since the 1990s, as illustrated in Figure 27.

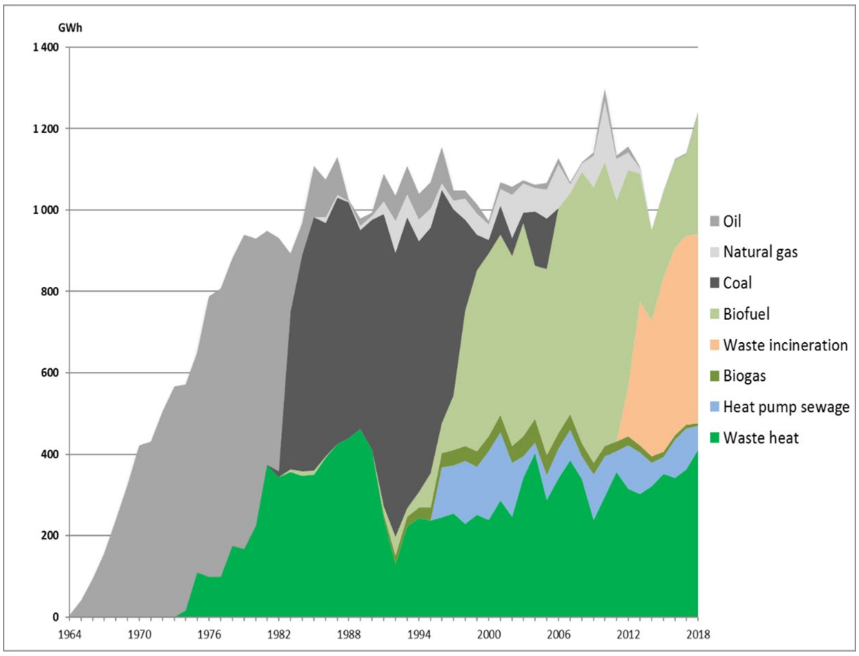


Figure 27: Energy mix evolution in Helsingborg DH (Source: Öresundskraft)

In 2019, the **energy mix** in Helsingborg's DH grid, in terms of heat production, was:

- 42% Waste-to-energy CHP (73 MW heat);
- 32% Waste heat mainly from a chemistry industry (45 MW);
- 18% Biofuel CHP (130 MW);
- 8% Heat pumps valuing waste heat from sewage, using green electricity (30 MW).

Evita interconnected DH system

There are **48 heat production sources within the Evita collaborative DH system**, including CHP plants, heat pumps, boilers (bio oil, natural gas and woodchips) and waste heat, all supplying the 3 district heating networks with **85°C hot water, raised sometimes in winter over 100°C, and 45°C in return**. Besides the Evita interconnector integrates also **3 DH storage tanks** for daily optimisation (3000 MWh in total), the largest being in Helsingborg (2000 MWh stored in a 40.000 m^3 tank). The existing fuel, plant technologies and waste heat suppliers were chosen based on cost and environmental criteria. As an example, the waste-to-energy plant Filbornaverket in Helsingborg has an energy recovery ratio of nearly 100 %.

Today, most of the **waste heat** comes from **chemical industries** (e.g. sulfuric acid production), supplying the DH grid since the 1970s in the frame of a long-term contract being renegotiated every 5 years. Waste heat from Helsingborg's **wastewater** utility is also recovered since 1995, supplying 80°C hot water to the DH system and collecting DH return water at 5-20°C. Smaller capacities have also been connected, among which a **copper factory** and a **crematorium**.

The joint operation optimisation of the interconnected networks is based on total production costs, and assured with a joint software, which is an integral part of the Evita project (and associated investments). Called "EO3" and designed by Energy Optima, this software seeks on a daily basis the production configuration with the lowest common variable cost meeting the heating demand and taking into account the capacity of each production plant, and the joint distribution network. Each morning, the 3 DH companies gather to validate the optimisation results.

The central feature of this software is a district heating **consumption forecast** based on current weather forecasts and historical outcomes of heat load. The parameters used in the calculations include fuel prices, taxes, variable maintenance costs, historical weather, electricity price forecast, plant availability and restrictions. The software is installed on Öresundskraft's server, and **all parties have full access to the software**.

Hence, prioritization is decided from an economical perspective. **The generation unit with lowest production cost is given priority** access to the network. Every plant has to fulfil nearly the same temperature demands.

Besides, the software is also used as a basis for the monthly invoice between the 3 DH companies, comparing actual costs with a reference case without the Evita interconnector.

In addition to the possibility of optimising production costs, the interconnection of the 3 district heating networks provides the following benefits:

- **Higher delivery reliability**: more heat production plants provide redundancy and reserve capacity;
- **Lower CO_2 emissions**: emissions are kept at a minimum as the most modern plants with the highest efficiency and the best fuel mix are often prioritised for heat production;
- **Maximising the use of local waste heat**, that would be otherwise wasted. The waste heat is better used, as larger distribution networks provide larger heat demand opportunities.

6.5.6. Sector integration approaches and local value creation

The DH operator follows closely the development of energy efficiency measures in buildings. Yearly **new connections to the DH and demand decrease due to energy efficiency in buildings counterbalance themselves**. Indeed, meanwhile Helsingborg's DH grid has an increasing number of connections due to demographic growth, the total **demand has remained stable for the last 10 years**.

Öresundskraft contributes to **smart cities initiatives** mostly through Internet of Things (IoT) systems and by providing data on real time consumptions to their clients.

The DH production is also **optimised depending on electricity prices, which ultimately results in a higher use of RES electricity.** When lower prices are observed, often due to a higher share of hydropower and wind electricity, the DH tends to produce more heat in CHP plants (and less electricity) and to use electricity-consuming technologies like heat-pumps.

The utility also provides reactive power nearly full time to the electricity grid thanks to two CHP plants, but these **services** have not been valued so far.

In terms of **local value creation**, DH in Helsingborg employs ca. 130 FTE, actively contributes to climate action targets and energy price stability, and given the utility is municipality-owned, its benefits come in addition to dividends that can be reinvested in the community.

6.5.7. Prospects

DH in Helsingborg has gone over time through a **deep decarbonisation process:** from oil to coal, and then to waste heat and wood pellets and waste-to-energy. It has **now become fossil fuel free.**

Öresundskraft considers the decarbonization of some existing plants to be the next step towards lower environmental impact. Indeed, **some plants like the waste-to-energy plants can still improve their environmental performance by reducing the plastic content of the incinerated waste**. The city seeks to find a solution based on carbon capture and storage (CCS) by the end of 2025 to make waste a zero or even negative-emissions energy source.

6.5.8. Conclusion

The Evita interconnector case study illustrates how **neighbouring cities and DH grids can collaborate by interconnecting their grids, to value synergies and improve their environmental and economic performance**.

The key success factors enabling the integration of RES and waste heat identified in Helsingborg can be summarised as follows:

i. **A national context favouring sustainable investments in heating**, through a series of policies put in place since the 1990s, including significant environmental taxes improving the price competitiveness of sustainable heat with respect to its fossil alternatives, in a completely liberalised market.

ii. The Swedish national context also favours **third party access to waste heat** sources, provided their integration is technically and economically viable, and in general the **public awareness on climate change** and willingness to contribute to climate actions is high.

iii. The **municipal ownership** of Helsingborg's DH utility has also influenced the progressive decarbonisation of the grid (from 100% oil to 100% RES and waste heat in about 25 years), in line with **the city's Climate and Energy Plan**, while allowing to implement a long-term energy strategy, accepting **long payback times** in DH investments.

iv. The Evita collaboration was built on **transparency and cooperation between the 3 municipal utilities, to reach a common goal of improved overall security of supply through production redundancy, economic and environmental performance**. They decided to base their cooperation on risk sharing, sharing costs and profits instead of negotiating a fixed price for exported or imported energy between them. Besides, the terms of the collaboration and **operational rules** for the interconnector have been clearly established in a **long-term collaboration agreement.**

v. The interconnection of the 3 neighbouring DH grids also enables a higher **uptake of waste heat.** Together with the **transparency on prices and open discussions with all parties** (consumers, third party suppliers…), the interconnected DH system has enhanced the capacity of the 3 utilities to **stabilize their prices** and remain competitive in the heating market.

vi. Finally, even if not directly related to RES integration, it is worth mentioning that thanks to the Evita collaboration, the 3 utilities also **share best practices and resources** (e.g., O&M workers), and have put in place **joint procurement** procedures enabling to obtain better prices using less internal resources.

6.5.9. References

- Euroheat & Power, Country by Country 2019 (link)
- International Energy Agency, 2019 Sweden Review

6.6. Case study Bordeaux (FR): Energie des Bassins

6.6.1. National context

The deployment of low-carbon DHC systems is one of the pillars of the French energy transition strategy, with an objective of multiplying by five the amount of renewable and waste heat and cold supplied through DHC systems by 2030, with respect to 2012, and **achieving 65% RES and waste heat in DH** by the same time horizon.

Table 8: Key facts for DHC in France

DHC in France - Key facts		
Regulation	Regulator / Supervision authority	• DHC is not a regulated activity in France • Other authorities: French national competition authority, DGCCRF ("*Direction générale de la concurrence, de la consommation et de la répression des fraudes*")
Regulation	Role of municipalities	• Responsible of the public distribution of heat • Owner of most of the networks (managed as concession or under direct control)
Regulation	Ownership (in terms of sales, 2018)	• 89% Public (7% direct management, 82% concession) • 11% Private
Incentives	DHC support schemes	• Heat Fund ("*Fonds Chaleur*") managed by the national Agency for Environment and Energy Management "ADEME": subsidies production and network facilities for DH networks using at least 50% of RES and waste heat sources. Since 2018, DC is eligible for the Heat Fund for the creation of networks with cold substations connected to new renewable cold production. • Reduced VAT rate (5.5% instead of 20%) for DH networks using at least 50% of RES and waste heat sources
Market	Total DH sales to customers (2018)	• Heating: 25,078 GWh (5% of the total heat market) • Cooling: 980 GWh
Market	Main clients (in terms of sales, 2018)	• 54% residential, 33% tertiary, 5% industrial, 8% others
Market	Main operators (in terms of turnover, 2017)	• Dalkia (44%), Engie (33%), Idex (7%), Coriance (7%)

The case study of "Energie des Bassins" (literally "Energy of the ponds") in Bordeaux is of particular interest, as it is **one of the biggest private networks in the country** (where DHC networks managed as a public service is usually the norm, as detailed in France country fact sheet in Annex 1). Therefore, this case is representative as it shows similarities with most of the DHC developments in France (involvement of the Municipality to initiate and steer the project, mobilisation of incentives through the national Heat Fund and the reduced VAT…), but it also highlights how a private network with limited control from public authorities (neither audit on technical efficiency nor applied tariffs…) can **work under market conditions and provide a qualitative and competitive service to its end-users**.

6.6.2. Local context

The first of the 3-axis composing the framework for the "high quality of life" strategy[25] of Bordeaux Metropolis is the acceleration of the energy transition, with the objective of meeting the energy demand with **100% renewable energy in 2050 (32% in 2030), including 30% of locally produced energy**. DHC has been recognized for a long time

[25] Document available in French on Bordeaux Metropolis website here

already as a very efficient tool to reach this double objective, and occupies a significant place in the energy strategy and planning of the metropolis.

As a result, Bordeaux Metropolis has already developed **5 major DHC networks** on its territory (including the "Energie des Bassins" network, which is the focus of this case study) for a **total energy production of 250 GWh/y as per today**. Additional 300 GWh are under development, and a total of 700 GWh is targeted with several existing and new urban areas already identified.

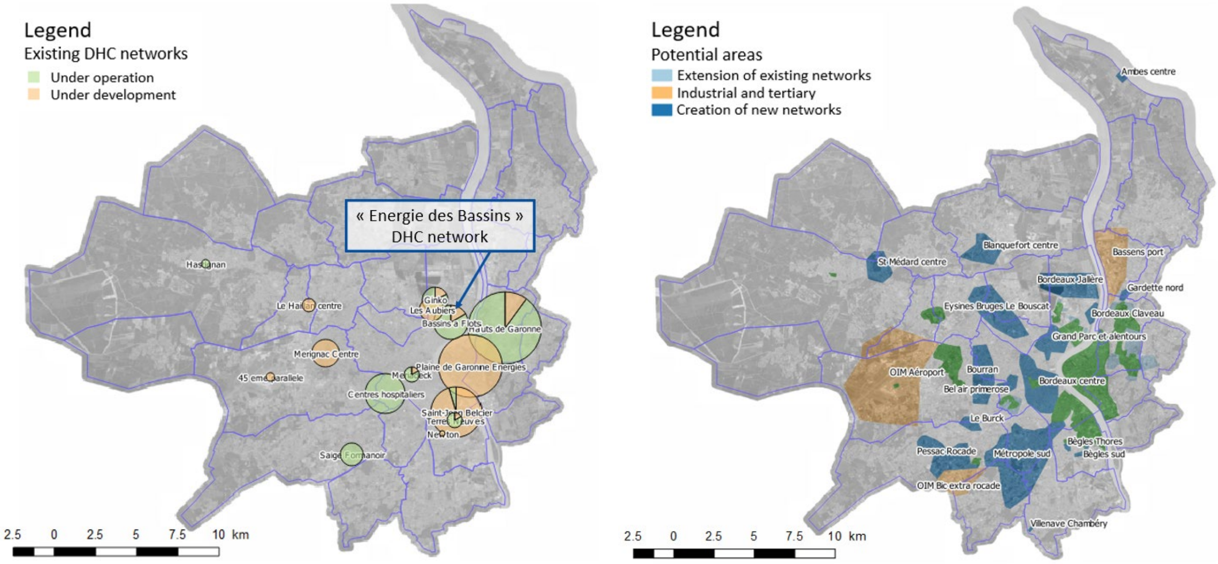


Figure 28: Maps of Bordeaux Metropolis DHC networks under operation or development (left) and DHC development potential (right)

There is not a single governance model to develop these multiple DHC networks in its territory, as Bordeaux Metropolis moves toward **either concession, direct control or private network** depending on the business and technical features of each case. The territory also provides a good panorama of the DHC **competition** in France since three of the four major operators (Dalkia, Engie and Idex) are active in the Metropolitan area.

On top of the energy strategy and planning, the Metropolis and Municipality of Bordeaux **continuously support the development of the DHC networks** by facilitating the relationship with real estate developers, the coordination with various stakeholders, the permitting process, the communication… In particular, the Metropolis **coordinates the different networks operators** (electricity, gas, DHC, waste water, telecommunication…) and establishes monthly meetings to ensure efficient and consistent operations.

Table 9: Key urban indicators for Bordeaux Metropolis

Bordeaux Metropolis		
Statistics (2017)	Population	791 958
	Demographic trend (2012-2017)	+1.4 %/yr.
	Density	1 370 inhab./m²
	Housing (number of dwellings)	420 238
	Housing in multi-flats buildings	143 230 (34%)
	Heating degree days (with a reference temperature of 15°C)	2 034
Regulation	Urban regulation	Zoning: new and renovated buildings in areas supplied by a "classified"* DH network are obliged to connect
	Building regulation (national)	Thermal regulation for buildings (RT2012): provides a construction bonus for virtuous DH networks (according to their CO_2 content)

**To be classified, a DH network must:*

- *have a renewable and waste heat share above 50% in its energy mix,*
- *provide energy metering equipment at each delivery point,*
- *and reach financial balance during its amortisation period.*

The **DHC network Energie des Bassins** (EDB), detailed in the following sections, is implemented on a **162-ha new eco-district expected to host 750,000 m² of buildings and 10,000 inhabitants**.

In this area, EDB supplies **heating and Domestic Hot Water (DHW) for nearly 100% of the buildings, and cooling for almost 50%**. The evolution of the annual energy sales, which are directly correlated with the eco-district development, are presented on Figure 29. Once the DHC network is completed in 2023, **the forecasted annual sales are about 40 GWh for heating and 8 GWh for cooling**.

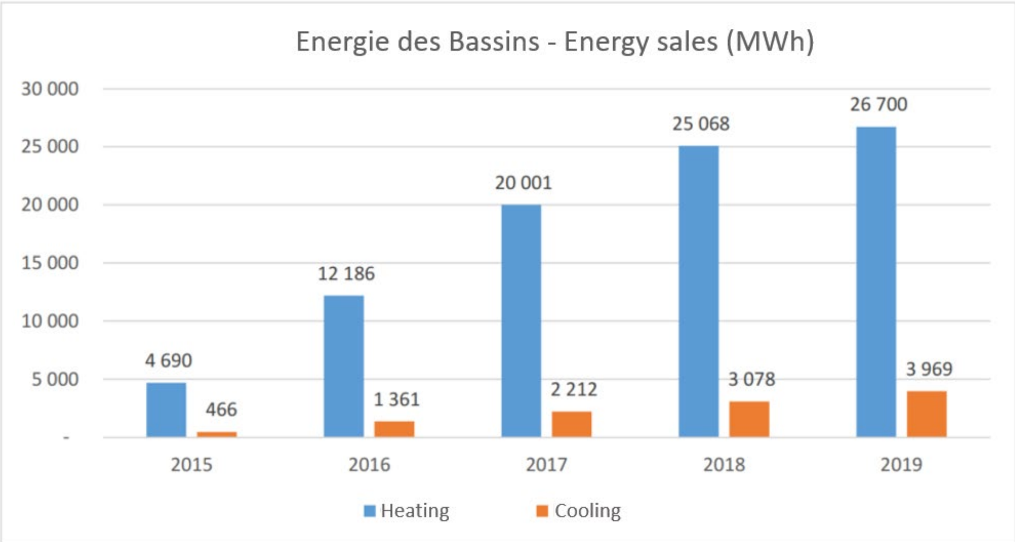


Figure 29: Evolution of EDB annual energy sales (source: EDB)

With an average price of about 90 €/MWh for heating, EDB solution is **competitive with the possible alternatives** (gas or electricity). However, pedagogical efforts with the end-users are often required since this competitiveness is true only when integrating all the various CAPEX of the solutions being compared (which is not always easy to understand since these CAPEX are borne by the real estate developer).

For cooling, EDB solution is particularly competitive in the "Chartrons" district (West) where a semi-centralized solution has been developed (see next Sections). In the "Bacalan" district (East), EDB proposes building-scale solutions (Bordeaux urban planning prohibits individual solutions for cooling in this new district) with electrical chillers or more innovative solutions like for the "Cité du Vin" (City of Wine in French), as presented in the next section.

Finally, as presented in Table 9, the connection to a low-carbon DHC system like the one of EDB also provides the real estate developers a **means to comply with the thermal regulation for buildings** ("RT2012"), which could turn into savings on other construction expenditures like isolation for example.

6.6.3. Presentation of the DHC system

As presented above, the DHC network *Energie des Bassins* was designed to supply the **new district "Bassins à flot"** (built around two main ponds as depicted on Figure 30) representing a total of 162 ha hosting housing, stores and other tertiary activities. The solution aims at an energy mix made of **at least 70% renewable and excess energy sources**. The DHC network started its operating phase in 2014 and delivers today around 80% of the forecasted total load. The construction phase is expected to be **completed by 2023**.

Table 10: Key facts and figures of EDB DHC network at completion (2023)

Key facts and figures	
DHC market share	DH: ca. 100 % of the covered area DC: ca. 50 %
RES share	70 %
CO_2 emissions	DH: 62 kg/MWh DC: 11 kg/MWh
Installed capacity	DH: 41 MW DC: 9,4 MW
Energy production	DH: 40 GWh/y DC: 8 GWh/y
Km network (double-pipe)	DHC: 18 km

Supported by a strong political will to develop local renewable energies, EDB has designed two district heating grids (not connected technically) using different local renewable sources:

- The **Chartrons DHC grid**, which uses waste heat from the effluents of the wastewater treatment plant "Louis Fargue" located in the district.
- The **Bacalan DH grid**, which uses woodchips collected in a 150 km radius to eventually power 2 biomass boilers.

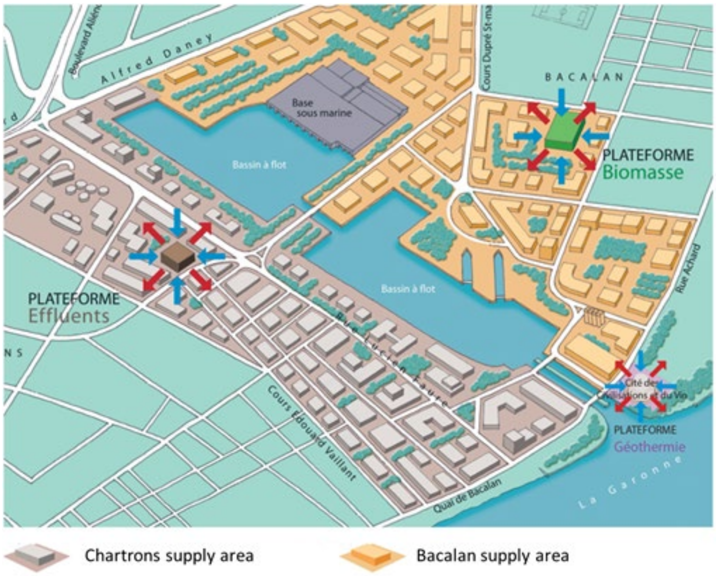


Figure 30: The new district of "Bassins à flot" and its DHC (source: EDB)

Figure 31: Chartrons DHC: WWTP, non-insulated pipes and substations (source: EDB)

The **Chartrons DHC grid** enables the valorisation of very low temperature energies. It recovers the calories from the "Louis Fargue" Waste Water Treatment Plant (WWTP) thanks to heat exchangers located at a centralised unit operated by EDB, in the immediate vicinity of the WWTP.

The DHC system is based on a a **mid-temperature loop** (8 km network) transporting water heated all year long between 12 and 25°C using the energy recovered from the WWTP and gas boilers when needed in winter (two times 3 MW and one of 600 kW, also located in the centralised unit). The water comes back to the centralised unit at around 7°C in winter and 30°C in summer.

The mid-temperature loop distributes the heated water to 40 substations located in every building connected. The substations comprise **decentralised heat-pumps (8,4 MW in total) and gas boilers (6,6 MW)**, connected to the loop by means of heat exchangers, to produce water for heating (45°C), domestic hot water (63°C) and cooling (7°C) as needed.

The buried mid-temperature loop is **not insulated** in order to dissipate the calories in excess in summer, when the heat pumps are mainly used for cooling demand. Therefore, the Chartrons DHC network does not require cooling towers.

The **Bacalan DH grid** supplies a 10 km insulated double pipe network with 90°C water from a biomass plant. The 25 MW Bacalan's biomass plant integrates:

- a 2.5 MW **biomass boiler** installed for the first construction phase (2014-2021);
- an additional 2.5 MW **biomass boiler** to be installed for the second phase (as of 2021);

- gas boilers for peak supply: 12.5 MW in 2020 and a total of 20 MW by the end of the construction phase;
- 2 x 60 m^3 **hydro-accumulators** to guarantee operation during the summer period.

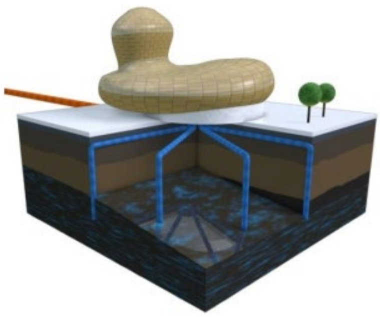


Figure 32: Illustration of the "Cité du Vin" supply solution (source: EDB)

An additional solution was designed for the "**Cité du Vin**", one of the emblematic museums of Bordeaux. For this major client, *Energie des Bassins* built a **geothermal system associated with heat pumps to satisfy the cold demand**. The cold production is achieved by 4 geothermal wells of 30 meters depth (producing a 16°C brine) and supported by heat pumps supplying 1 MW of cold. The museum is **also connected to the Bacalan DH** grid in order to cover the 750 kW heat demand.

The use of geothermal energy to produce both heat and cold is under analysis to find a profitable operating mode. At the moment, geothermal energy is only used to supply heat as a back-up of the Bacalan DH grid, due to a low Coefficient of Performance (COP) given the temperature levels at stake.

6.6.4. Governance and business model

Governance and ownership

The network is owned and operated by the project company "Energie des Bassins", structured as follow:

- 60% of Mixéner, a company made of Bordeaux Métropole Energies (a public-private company owned at 68% by Bordeaux Metropolis) and the DHC private operator Idex;
- 40% of Dalkia, owned at 100% by EDF group ("Electricity of France").

As depicted in Figure 33, the project company relies on a relatively complex ownership structure, where Bordeaux Metropolis and three of the four major DHC operators in France are involved. The Board of Directors is composed by 3 members from Mixéner (2 from Bordeaux Métropole Energies and 1 from Idex) and 2 members from EDF.

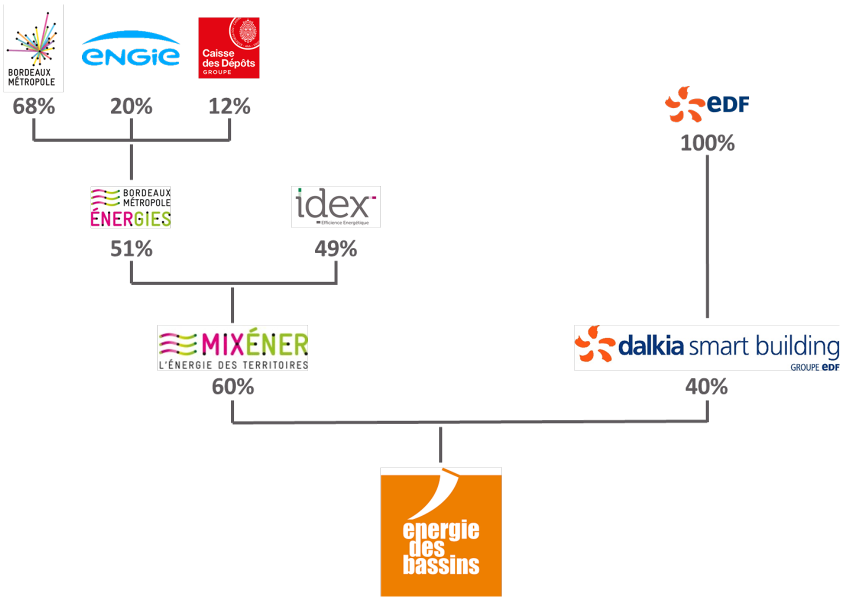


Figure 33: Energie des Bassins ownership structure (source: own diagram)

Even though EDB is a private network, **Bordeaux Metropolis is directly involved through the ownership structure and as a key player for the creation of the network**. Indeed, the Municipality and Metropolis of Bordeaux already had in 2009 a clear vision for the project of the new "Bassins à Flot" eco-district and wanted to implement a real energy coherence.

Despite the commercial risk which was very high at that time for the operator (new buildings with no guarantee to connect to the DHC network), local authorities managed to reunite Mixéner and Dalkia with the objective to supply heat and cold from clean energies to all the future new buildings of the eco-district during 30 years. To mitigate this commercial risk, Bordeaux Metropolis played a significant role in the establishment of an **agreement with the eight main real estate developers** in the area and decided to manage the asset as a **private network**.

Strategy and offer

EDB sells **heating** (and domestic hot water) and/or **cooling** (details in next section). The "Bassins à Flot" district is entirely new (the construction phase spreading out over 2012-2025), so EDB supplies **new buildings only**. The network is not "classified" (see Table 8 and Table 9) so there is no obligation to connect for new or renovated buildings.

The connection contract is established between EDB and the real estate developers for 30 years (with **no disconnection right**), the latter paying **connection fees.** During operation, the end-users pay **a subscription and the energy consumed** (through a fix and variable component respectively, detailed in next section).

The connection fees are proportional to the buildings' surface in m², and not to an estimated contract capacity in kW which would be more reliable for EDB. In order to mitigate its exposure to buildings that could have a high energy consumption ratio (kWh/m²), EDB has set **a dissuasive tariff for buildings that would go beyond the Primary Energy Consumption (PEC) targets set by the current national building regulation** ("RT2012"). In addition, **EDB offers a strong technical support to the real estate developers** and helps them to ensure an efficient design of their buildings and equipment in order to limit their energy consumption and avoid the dissuasive rates. In this way, EDB is part of a virtuous approach where the energy provider not only provides green energy but also contributes to a rational and efficient consumption of this energy.

This early involvement of EDB in the buildings' design **also allows the DHC operator to optimize the design of the substations** (e.g. consultation with the architect), **which is particularly important in such a system with semi-centralised substations providing heat and cold** (see Section 6.6.5 on Chartrons district).

Figure 34: Model of the "Bassins à flot" district under construction (source: Bordeaux Metropolis)

EDB owns and operates all the substations, and provides the **technical specifications** for secondary networks that the real estate developers must comply with in order to connect to the DHC network.

EDB installs **smart meters** in each building (the cost allocation between each end-user is set by the building management) and invoices the customers monthly. EDB has 80 customers (real estate developers during the building construction phase and then building managers during operation) and has established an individual direct relationship with each of them.

Today, as both the district and the DHC network are still under development, the priority of EDB is to ensure an efficient service with no technical failure rather than to proceed to the detailed optimization of the operation. However, particular care is already paid to the **fine-tuning of the customers' contracted capacity** and mechanisms such as a bonus to incentivise the optimal return temperature from customers could be set in the future.

Complementary businesses like energy services on the secondary network could also be proposed by EDB. However, as the shareholders composing the company are competitors on many market segments, the project company has decided to avoid any possible conflict of interests and not to develop this commercial strategy.

Financial model

Although EDB is a private network (which authorizes the operator to apply different tariffs negotiated with different customers e.g.), it proposes a **single tariff (for both**

residential and tertiary clients and for both Chartrons and Bacalan districts) fixed over the 30 years of the contract.

The tariff structure for the heat and cold delivered at the substations' output is presented in the table below. Like the other DHC networks presenting a high renewable and waste energy share, EDB's network has a **relatively high fix component** (which covers the operation and maintenance costs as well as the significant investment costs) and a **relatively low variable component** (which covers cheap or almost free renewable energy like geothermal, or waste energy such as the heat recovery from the WWTP). This explains why the fine-tuning of customers' contracted capacity is particularly sensitive on this type of DHC network (see discussion in the previous section).

Table 11: Tariff structure for EDB DHC network

	Prices observed in 2020	
	Incl. VAT	Excl. VAT
Heating		
Connection fees	27,2 €/m²	32,7 €/m²
Variable component	29,1 €/MWh	30,7 €/MWh
Fixed component	92,5 €/kW	97,6 €/kW
Cooling		
Connection fees	20,7 €/m²	24,8 €/m²
Variable component	51,9 €/MWh	62,2 €/MWh
Fixed component	82,9 €/kW	99,5 €/kW

These tariffs are **revised quarterly based on indexation formulas** detailed in the contract. For the variable component, the formula refers to the actual energy mix observed over the period and is based on national indexes related to the price evolution of biomass fuel, electricity and gas (only electricity for cooling). For the fixed component, the formula is based on national indexes related to the price evolution of production activities and labour, for example.

Like for the majority of the DHC networks in France today, EDB is able to propose competitive tariffs versus individual solutions based on gas or electricity thanks to the financial support provided by the national Agency for Environment and Energy Management "ADEME" (see section 0). Once the development phase is completed in 2023, EDB's network should have benefitted from **a total of 5 M€ investment subsidies (2.5 M€ having been paid already) out of a 32 M€ total investment**. The granting of these subsidies is conditional on:

- maintaining a renewable and waste energy share above 70% of the total energy mix,
- maintaining the efficiency of the system (COP of the heat pumps, thermal losses…),
- monitoring the network's performance and sharing the corresponding data with the ADEME.

In addition, as EDB's DHC network has a renewable and waste energy share above 50% of the total energy mix, **the end-users benefit from a reduced-rate VAT** (5.5 instead of 20%) on the variable component for heating (the fixed component for heating is already at the same reduced-rate, while both components remain at 20% for cooling).

As a result, **EDB's business is profitable** and generates today an annual turnover of about 5 M€ (the connection fees still weighing for about 35%) and a net result of about 2.5 M€.

6.6.5. Use of RES and/or waste heat/cold

Launched with a strong political will to **create a virtuous DHC system based on local renewable sources**, the DHC project in the "Bassins à flot" district was based on three local energy sources:

- **Biomass from woodchips**, originating from forests in a maximum radius of 150 km:
- With a total of 2.8 millions hectares of forest, the Nouvelle Aquitaine region is the first wooded area in France. Hence, a biomass platform appeared in the top first choices for supplying the DHC grid.
- The **heat recovery from the renewed urban Waste Water Treatment Plant (WWTP)** Louis Fargue:
- The immediate vicinity of the urban WWTP and its upgrade in 2012 into a larger station able to process up to 276,000 m^3 of effluent per day made it a natural top of the list solution for the DHC grid.
- **Geothermal energy at 30 m depth** in the alluvial sandstone of the Garonne River (the produced water being rejected back to the river bed at around 32°C):
- On the riverside of the Garonne river, geothermal energy was identified since the beginning as a potential solution for the DHC network. It was finally implemented for the cold demand of the museum "Cité du Vin", located in the Bacalan district.

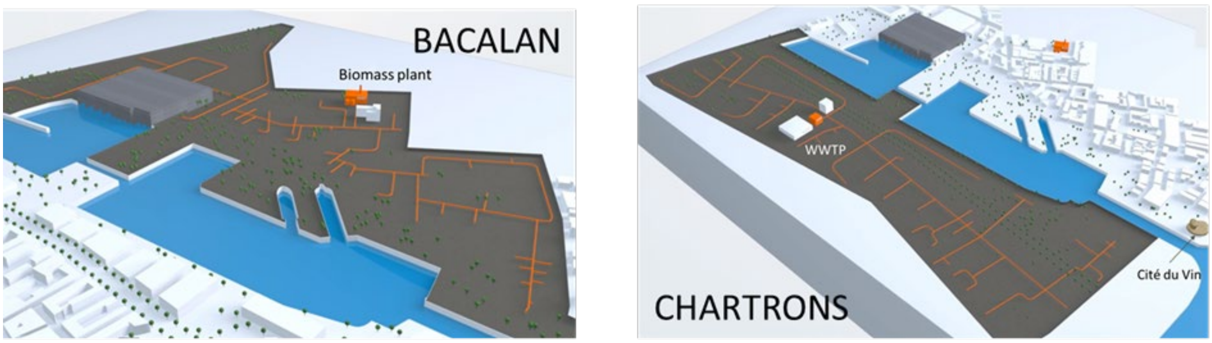


Figure 35: Bacalan and Chartrons DHC (source: EDB)

The energy mix reaches a **70% ratio of local renewable or waste energy sources** with 50% from biomass and 20% from heat recovery of the urban WWTP. In total, it avoids the annual emission of 8,000 tons of CO_2 in the atmosphere.

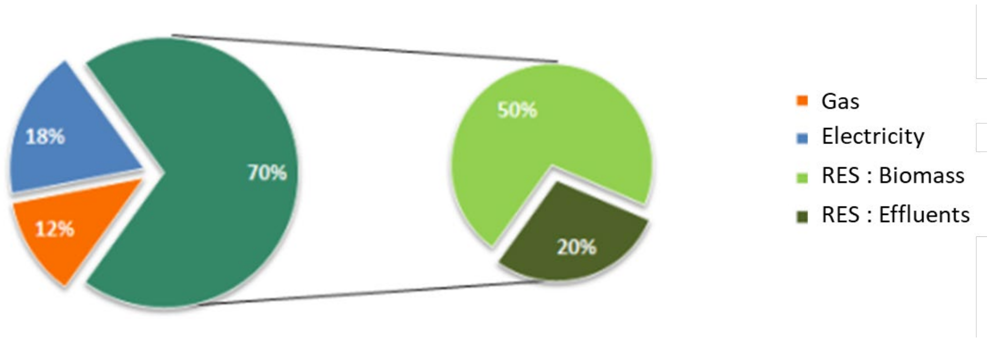


Figure 36: EDB energy mix (source: EDB)

As the "Bassins à Flot" develops, the DHC network has managed to maintain a renewable and waste energy share above 60% (see Figure 37). This has been achieved thanks to:

- a **modular approach of the biomass facilities development** (two biomass boilers of 2,5 MW each commissioned at different years),
- the implementation of **thermal storage facilities** (two times 60 m^3, equivalent to 3,5 MW over 1 hour),
- the **decentralised design of the substations** on Chartrons DH network, which include their own heat pump and gas boiler and thus allow adjusting the production capacities as the district develops.

This renewable and waste energy share should settle at 70% in 2023, by the end of its construction and the completion of the urban district.

Figure 37: Renewable ratio and connected surface evolution

The centralised unit of the Chartrons DHC grid is located just next to the urban WWTP. **The DHC operator has a contract with the WWTP based on the surface of the exchangers** used to recover heat from the effluents, which makes **the price of the recovered heat very competitive and enables a good integration of this clean resource**. This contract does not include any minimum nor maximum quantity to supply or to off-take from any of the two parties. However, the DHC operator must comply with specifications on the quality of the water which is then rejected into the river (2 to 3 quality measurements are carried out per year).

The WWTP thus deviates part of its effluents to the heat recovery unit. The flow rate can reach up to 3,600 m^3/h but usually remains around 1,000 m^3/h to fill a 2,000 m^3 buffer storage tank as illustrated below on Figure 38.

Two heat exchangers are designed to accommodate 200 and 300 m^3/h of effluents and to recover heat from these. Both are plate heat exchangers. If the technology is compact, it presents several issues with the maintenance and has a tendency to get quickly clogged up. A new **platular heat exchanger** with a 500 m^3/h capacity will be installed in 2021. This new technology, although less compact, should enable a simpler and faster maintenance by allowing to simply use pressurized water rather than chemical products (caustic soda…) used by the plate technology.

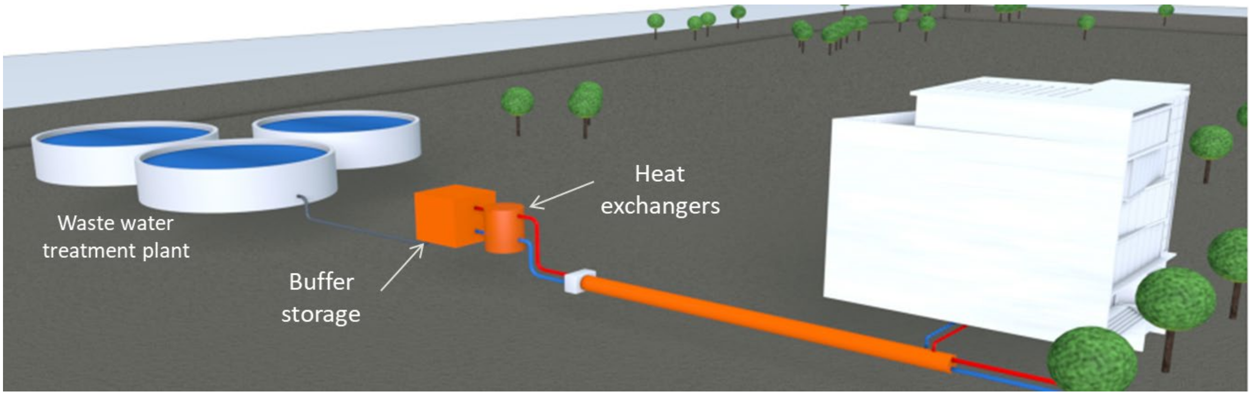


Figure 38: Heat recovery from the waste water treatment plant

The recovered heat is then distributed to the decentralised substations thanks to the mid-temperature network (loop) and heat exchangers. There, it is **processed by heat pumps to produce heat and cold** according to the needs of each connected building. Each substation is working independently from the others according to two main modes:

- If the heat demand is dominant (winter): the heat pumps produce heat to match the demand and the **excess cold** is evacuated by the loop (through the return pipe) and can be recovered by other substations with cooling needs.
- If the cold demand is dominant (summer): the heat pumps produce cold and the **excess heat** is evacuated by the loop (through the return pipe). Again, this excess heat can be recovered by other substations with heating needs (e.g. domestic hot water).

This system is designed to accommodate, for each substation, the fluctuation of the heat and cold demand through the year. The fine-tuned optimization of these different production units is performed continuously thanks to a partly automated process. **The COP of the heat pumps is around 3,5 to 4 all year**.

Thus, Chartrons mid-temperature loop has been designed to make the most of the **very low temperature energy source from the WWTP and to mutualize the means of cooling and heating production**. It is possible and particularly relevant as the new eco district where it is implemented is composed of **high-efficiency buildings with low temperature regimes for heating**.

6.6.6. Sector integration approaches and local value creation

As presented in the previous sections, EDB has developed a **major local synergy through the heat recovery from the nearby urban WWTP**. This is materialised by a long-term contract between the two parties (DHC and WWTP) which has been enabled by the facilitation from Bordeaux Metropolis and by the good relationship developed by the two operators.

Regarding building renovation, the **concerted development of the 162 ha new district "Bassins à Flots" and EDB DHC network** is obvious as they both depend from each other as discussed in sections 6.6.2 and 6.6.4. According to the national building regulation (RT2012), this new district is designed to comply with the current Primary Energy Consumption thresholds (in kWh/m²). As discussed in section 6.6.4, **not only has EDB taken these thresholds into consideration for the design of its DHC network, but the DHC operator is also supporting the real estate developers to ensure an efficient design of their buildings and equipment** in order to limit their energy consumption.

As discussed in section 6.6.4, EDB wishes to develop **consumer-oriented services** in the near future (with possible bonus to incentive return temperature, for example). The operator is already actively assisting its customers in fine-tuning their contracted capacity in order to optimize their energy bill.

In addition to the direct and indirect local employment created and the corresponding local taxes generated, the EDB DHC network provides the new urban district "Bassins à Flots" with a good visibility and an **attractivity reinforced by energy savings, the use of clean and local energies, and the overall competitiveness of its offer**.

6.6.7. Prospects

EDB has **already captured all the commercial potential authorised by the urban planning** of Bordeaux Metropolis within the "Bassins à Flots" district.

According to the initial contract signed with the Metropolis, EDB can look for potential new connections out of the 162 ha area of the district within the limit of 500 m. In addition, the DHC operator has the obligation to study any connexion request from buildings with surface exceeding 500 m^2. However, **extension cases are very limited at the moment as the priority remains the upcoming clients of the district**.

6.6.8. Conclusion

Energie des Bassins (EDB) DHC network showcases **how low-carbon DHC systems can develop in new urban areas, and evolve with these** while continuously optimising their operation and energy mix.

The key success factors enabling the integration of RES and waste heat can be summarised as follows:

i. **National support schemes for low-carbon DHC systems.** For EDB, this support mainly took the form of a reduced VAT for DHC sales, significant investment subsidies (around 15%), and the consideration of the low CO_2 content of the DHC network as a means for real estate developers to reach building regulation's energy requirements.

ii. **A clear vision and a strong support from Bordeaux Metropolis to initiate the project.** At the heart of its strategic framework to achieve a "high quality of life", Bordeaux Metropolis immediately identified the need of an energy coherence for this new urban eco-district. To meet this requirement, the Metropolis got involved in a concrete way, through its participation as a shareholder of the DHC project company. By doing so, it was able to reunite major DHC operators to carry out this ambitious project, playing also a key role as a facilitator with the real estate developers.

iii. **A competitive solution supplying heating for nearly 100% of the district's buildings, and cooling for almost 50%**. This competitiveness is achieved thanks to the favourable national support scheme mentioned earlier, but also thanks to the efficient design and operation of the network (e.g. combined heat and cold production through heat pumps in decentralised substations) and to the integration of cheap or free renewable energy sources (e.g. excess heat from the WWTP and geothermal energy).

iv. **A technical match between local low-temperature energy sources and new buildings' temperature regimes.** Supplying a district made of new buildings with low-temperature regimes for heating allowed EDB to integrate low-temperature clean and local energy sources (excess heat from the WWTP and geothermal energy) coupled with heat pumps to provide both heating and cooling with high efficiency. In addition to the local biomass fuel, this integration allows EDB to reach a 70% share of renewable and waste energy sources in its production mix.

v. **An innovative and modular design to supply heating and cooling and to accommodate the development of the new urban district.** The implementation of a mid-temperature loop supplying decentralised substations equipped with their own heat pumps and gas boiler, as well as the modular development of the biomass plant allows to adapt very efficiently to the district development (spread over 14 years) and to ensure the economic viability of the project. The implementation of tailor-made solutions for particular clients like the geothermal project for the "Cité du Vin" also contributes to the flexibility of EDB's offer.

vi. **A real involvement of the operator with its clients.** EDB offers its strong technical support to real estate developers very early (to ensure an efficient design of their building and equipment) and later it advices the end-users (e.g. fine-tuning of the contracted capacity). In this way, EDB is part of a virtuous approach where the energy provider not only provides green energy but also contributes to a rational and efficient consumption of this energy.

vii. **Synergies with other urban infrastructures.** The clear synergies developed with the WWTP and the real estate developers ensure a consistent and efficient urban development as initially wished by the Metropolis.

6.6.9. References

- Master plan for DHC on the Metropolis, Bordeaux Metropolis, 2020
- Presentation of EDB DHC network, EDB, 2020
- Annual operating report, EDB, 2019
- EDB tariffs and invoicing, EDB, 2020

6.7. Case study Querfurt (DE): modernising and decarbonising a DH system through local biogas production

6.7.1. National context

Germany aims at becoming climate neutral by 2050 at the latest and released at the end of 2019 a "Climate Protection Programme" with ambitious intermediary targets for 2030. At the heart of this programme is a new national CO_2 pricing system for the transport and heating sectors coming into effect in 2021 (progressive increase between 25 €/tCO2 to 60€/tCO2 in 2026). Further measures intend to make DHC grids more efficient and contribute to convert them to renewable energies and waste heat.

Table 12: Key facts for DHC in Germany

DHC in Germany - Key facts		
Regulation	Regulator / Supervision authority	• DHC is not a regulated activity in Germany • Other authorities: Federal Cartel Office (*Bundeskartellamt*), national competition authority
Regulation	Role of municipal owned companies	• Main owners of CHP facilities and operators of DH systems • Can offer their utility services to other regions of Germany • Can propose incentives through their local strategy
Regulation	Ownership (main schemes)	• Public-Private Partnership (PPP) • Municipality owned (*stadtwerke*) • Private
Incentives	DHC support schemes	• Heating Network Systems 4.0 Programme for DH covering 50% of the annual consumption with RES with low temperature • Grants from the Federal Office for Economic Affairs and Export Control (*BAFA*), through the Market Incentive Programme (*MAP*) • Feed-in premiums and tenders for renewable electricity, including CHP • Low interest rate loans and grants by the public bank KfW, through the MAP • Energy tax on fossil fuels • Environmental tax (increasing CO2 tax applying since 2021)
Market	DHC Final Energy Consumption	• DH : 111 154 GWh (2020 without industrial heat) • DC : 291 111 MWh (total sales in 2017 – Euro Heat and Power)
Market	Main clients (in terms of sales, 2020)	• 41% residential, 38% industrial, 21% tertiary
Market	Main operators (in terms of turnover, 2017)	• Vattenfall, Stadtwerke München, Wärme Hamburg, MVV, EnBW, enercity AG, Dalkia, Engie, Getec

While in 2017 DH represented 14% of the national heat market in the residential sector, **DH uptake is higher in Eastern Germany**, for historical reasons. Many of those DH systems were originally based on fossil fuels, and since the national energy transition (*Energiewende*) started in 2010 have progressively integrated renewable energy sources. **The case of Querfurt is representative for small and medium-sized cities in Eastern Germany,** with industrially manufactured apartment buildings and a DH system having gone through a modernisation and decarbonisation process, which should be further encouraged by the upcoming CO_2 national tax increase to reach a majority of low-carbon energy sources.

6.7.2. Local context

Querfurt is a 10,500-population town located in the region of Saxony-Anhalt. Around 1/3 of its dwellings are owned by the **municipal housing association WBQ**[26] (Wohnungsgesellschaft mbH Querfurt), which took over the activity of the former State-owned housing association in the aftermath of the German reunification in 1990.

[26] https://www.wohnen-in-querfurt.de/

This housing association also owns the city's **DH grid, supplying the district "Querfurt South"** and built in the 1970s. Most of the buildings supplied by DH in Querfurt are prefabricated apartment buildings built between 1971 and 1985, owned by the municipal housing association (WBQ) and to a lesser extent by private owners.

Table 13: Key urban indicators for Querfurt

		Querfurt City
Statistics	Population (2019)	10 481
	Demographic trend (2011-2019)	- 1.09 %/year
	Density	67.35 inhab./km²
	Housing (number of dwellings) in 2011	9 699
	Housing in multi-flats buildings in 2011	3 370
	Heating degree days (with a reference temperature of 15°C)	3 395
Regulation	Building regulation (national)	• Building Energy Act (Gebäudeernergiegesetz GEG), 2020

As many other rural communities in Eastern Germany, Querfurt faced the **migration of part of its population** to Western Germany after the German reunification. One of the measures undertaken to avoid so, was the improvement of living standards through an **urban renewal** programme, including the **energy renovation** of apartment buildings in the early 1990s. The buildings that were renovated included those supplied by DH. However, this urban renewal programme did not include the DH grid, which was also facing inefficiency issues, decreasing sales, and becoming less competitive than the alternative gas supply.

In the beginning of the 2000s the situation of the DH grid became unsustainable, as further detailed in Section 6.7.5. The inefficiency of the network led to a price that was too high, and customers started to disconnect and install standalone gas solutions, which were more competitive in price. In 2009 the possibility of decommissioning the DH grid was on the table, and the housing association operating the DH grid called upon external support to investigate the options and decide on the DH grid's future.

The solution proposed by the operator's partner and advisor (Tilia[27]), further explained in the following sections, allowed to maintain the DH supply, and to reach remarkable results. It consisted in a **complete reengineering of the DH production, modernising and decarbonising it.** The project included a comprehensive set of measures, including the improvement of energy efficiency, the installation of a new biogas unit using local agricultural waste to replace natural gas, and the creation of a dedicated DH company owned by the housing association, resulting in more attractive DH tariffs, a better quality DH offer, and significant local value creation (see Section 6.7.6).

DH is today the most competitive heat supply, around 5-10% cheaper than the alternative natural gas solutions, and with optimistic prospects in terms of price competitiveness, due to the upcoming CO_2 tax increase (see Section 6.7.7).

[27] https://tilia.info/

6.7.3. Presentation of the DH system

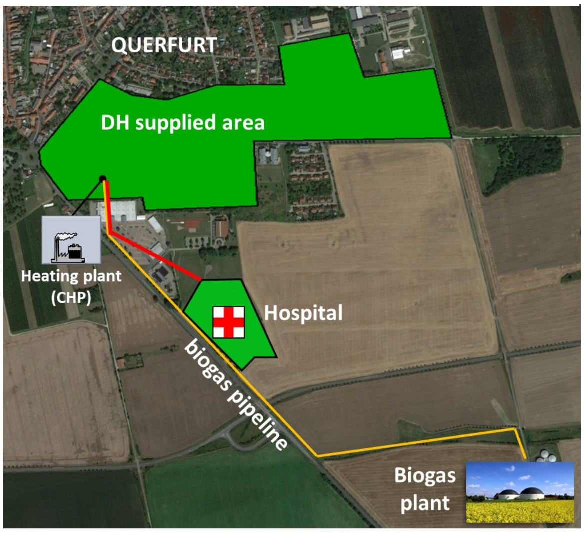
Located in the southern part of Querfurt, the current DH facilities, resulting from the above-mentioned project, were **commissioned in 2014** after 4 years of conception and construction. The process which led to the successful renovation of the DH system is presented in Section 6.7.5.

Since 2014, a **biogas plant from local agricultural waste is feeding a 500 kW CHP unit** supplying the grid. An additional 9.7 MW gas boiler ensures the rest of the supply and peak loads. The current production mix consist of **30% biogas and 70% natural gas,** and the RES share is expected to increase in the future (cf. Section 6.7.7).

Figure 39: Key facts and figures of Querfurt DH network

Key facts and figures (2020)	
DH market share	95% of the area covered by the grid
RES share	30 % (planned to increase in the future)
CO_2 emissions	125 kg/MWh
Installed capacity	10.2 MW
Energy production	15 GWh/y
Km network	5 km

Figure 40: Querfurt DH supplied area and production plants (source: Tilia)



Operated and managed by the new DH company created by the modernisation project, **Fernwärmegesellschaft Querfurt mbH (FWQ)**, 100% owned by the housing association WBQ and therefore by the municipality, the heat is produced in the heating plant and **supplied at 85 °C**. The return temperature is around 45 °C. The heat is mainly sold to apartment buildings (renovated in the 1990s, as mentioned before) with an average consumption of **70 kWh/m²/year**. Following the project, the local hospital was also connected to the grid through a dedicated pipe, as DH became more competitive than its own gas CHP.

6.7.4. Governance and business model

Governance

The DH company FWQ is fully public. Its creation provided the city of Querfurt with a new operational tool to implement its energy strategy while maximising local value creation. This new municipal operator not only owns and operates the DH network, but is also able to offer energy efficiency services (e.g., energy efficiency in public lighting and in the public swimming pool). There is not DC demand in the city, apart from the hospital which has its own cooling solution.

The modernisation project is a result of a performance-based public-private partnership. The private actor (Tilia) got the contract award thanks to its Impulspartnerschaft®[28] offer, where a number of KPIs and targets were set (e.g., heat price and CO_2 reduction, sales stabilisation, proposing a viable business model for the DH grid…). The targets were established in 2009 at contract award stage and referred to 2013. As the results sought

[28] https://tilia.info/de/tilia-modell (in German)

were reached, a yearly bonus payment was paid to Tilia between 2013 and 2021, defined as a percentage of the value created thanks to the project.

Business model

Aiming at reaching the commonly agreed targets, the proposed solution, further explained in section 6.7.5, took advantage of the **national support schemes** available at the moment, particularly interesting for **biogas CHP** as investment subsidies were granted by the Market Incentive Programme (MAP) and a feed-in-tariff was available through the Renewable Energy Act (EEG) and the CHP Act (KWK-G). The DH network could therefore receive a **new revenue stream from electricity sales** that was enough to recover the investments, the heating production being a by-product used for DH.

The project represented **3.5 MEUR investments**, financed at 70% by debt funding. Its business model was designed to obtain a margin of 3-5% over costs for the DH operator, with a tariff adjustment being done in case higher margins were reached **to share the benefits with consumers** and remain competitive in price. The benefits of the DH grid are therefore shared between the city and its citizens.

Contracts with clients have a 10-year duration, with the possibility to extend to 5 additional years. Disconnection is possible at the end of the contract, and also during its duration provided the fixed part of the tariff is paid for the remaining duration of the contract.

Following the modernisation project, DH prices were reduced significantly and stabilised, making DH more attractive and increasing the number of connections.

The DH business is stable and profitable. Current tariffs are as follows:

- <u>Connection fee</u> for new clients covering connection costs;
- <u>Fixed part:</u> 20 EUR/MW/y in average ;
- <u>Variable part:</u> 65 EUR/MWh in average.

6.7.5. Use of RES

The integration of RES in Querfurt's DH system followed a methodical process that could be replicated in other cities.

The starting situation

As stated before, the DH operator inherited an old, rather inefficient gas fuelled DH grid with high prices. In the first decade of the 21st century, social and economic problems linked to inefficient energy supply led to the **question of whether to stop the DH supply**, as it was too expensive (130 EUR/MWh) and faced heavy fixed costs due to disconnection of large customers.

Querfurt was at that time looking for an overall energy strategy that would fit the city development plans. **The DH system could play an important role** in that strategy. However, in order to keep the DH heat supply, some conditions had to be met, namely:

- **Price decrease**,
- **Decarbonisation** of the DH system in accordance with the national laws,
- **Connection of new buildings** to the grid.

Modernisation project methodology and development

In this context, the retained solution was the result of a thorough analysis carried out between 2009 and 2013 based on a **holistic assessment and ranking of all energy scenarios and potential projects**, building on the city's fundamental scenarios (demographics, city development, economic development). The best scenario resulted from the combination of the existing generation plants with a new base load generation based on locally-produced biogas (see Figure 41).

The project was designed in **close connection with local stakeholders**. By conducting a comprehensive benchmark of all solutions based on economic, environmental and social welfare criteria established with the municipality, the solution chosen also achieved the **reduction of dependency on natural gas** price and **increased the local added value**. It created synergies with the local agriculture, public buildings (e.g., hospital) and developed energy efficiency services.

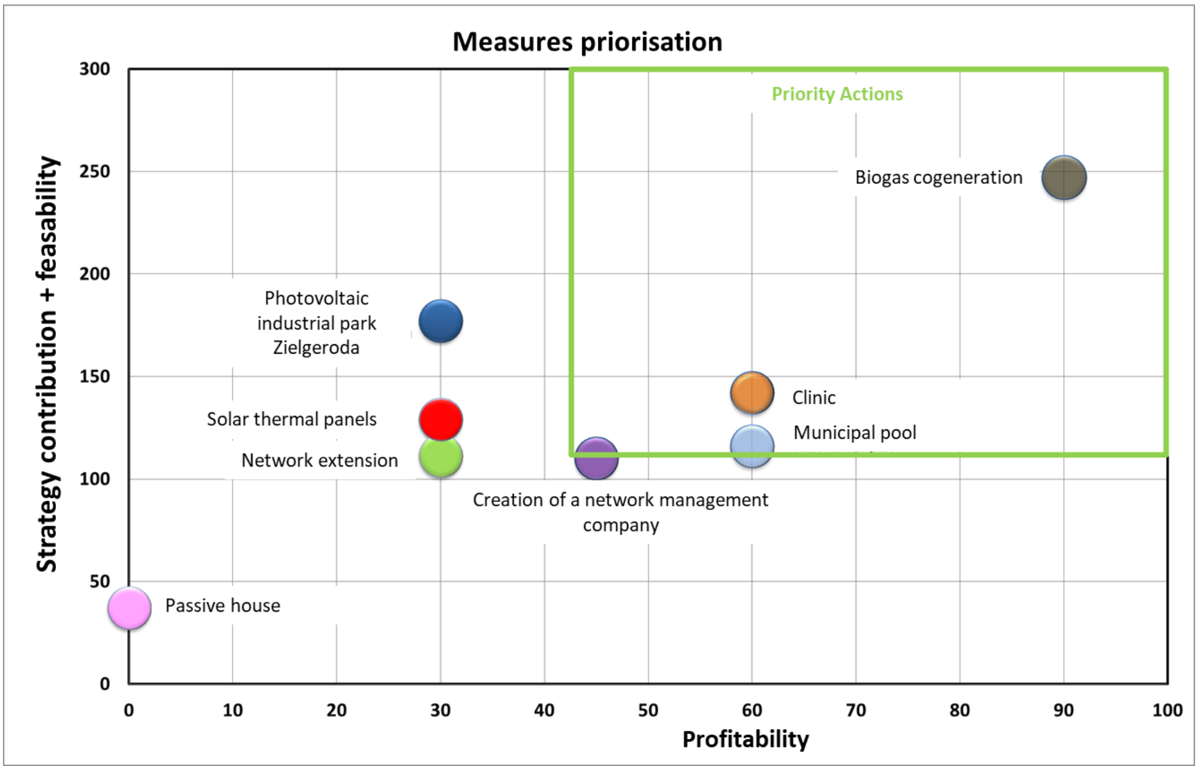


Figure 41: Decision-making matrix used to assess and rank solutions (source: Tilia)

The project envisioned the construction of a new **biogas plant using local agricultural waste** (mainly caw manure and crop residues, complemented with corn) and connected to the existing heating plant via a **raw biogas pipeline of 2.5 km** and a new **cogeneration system** which provided new revenues to the DH system through the sale of electricity, overall enhancing the business plan.

A **joint venture** was created in agreement with **the agricultural association of local farmers** (50% housing company WBQ, 50% agricultural association), which built, owns and operates the biogas plant and the pipeline connecting it to the CHP unit. This joint venture has a long-term supply contract with the DH company.

Figure 42: Querfurt biogas plant (source: WBQ)

Modernisation project results

Commissioned in 2014, the project met its high expectations and showed outstanding **results**:

- **Carbon emissions reduction: 40%**
- **Average reduction of the heat bill: 30%**
- **City return on equity: 25%**
- **Sales increase: 17%**

Among other new customers, the local **hospital**, which already had its own CHP, chose to connect to the DH grid as it turned to be cheaper. This brought more than 100 k€ savings per year to the hospital (around 20% of its energy bill).

The municipality-owned housing company used this opportunity to look for further optimization potential. It has for instance started the conversion of its street lighting. Therefore, **the refurbishment of the district heating system was used as a catalyser for a broader energy transition**.

Transition towards a decarbonised DH system

The DH system will continue its decarbonisation path to contribute to the national and regional climate targets. The approach retained by the DH operator is proactive and business-oriented, meaning that only economically viable projects, competitive in price against natural gas, will be implemented. **Policy incentives and support schemes** such as the increase of CO_2 taxes to fossil heating will therefore play a key role in the decarbonisation process (cf. Section 6.7.7).

6.7.6. Sector integration approaches and local value creation

The modernisation project allowed to value **synergies between the agricultural and energy sectors.** The local agriculture cooperative Agrargenossenschaft Querfurt eG (AGQ)[29] is an integral part of the project, as it owns 50% of the biogas plant and pipeline

[29] https://www.ag-querfurt.de

(through the joint venture created with the housing association, BQC Biogas Querfurt GmBh & Co. KG). This project provides the cooperative with additional revenues and services.

Maximising local value creation was one of the key objectives of the project. To assess this value creation *ex-ante* and *ex-post*, a specific tool was created. The value effectively created is estimated at around 200,000 EUR/y plus externalities (CO_2 emissions' reduction, increased attractiveness of the district due to lower heating costs, etc.). The project created **1.5 FTE** jobs, while **maintaining existing employment** related to the DH network.

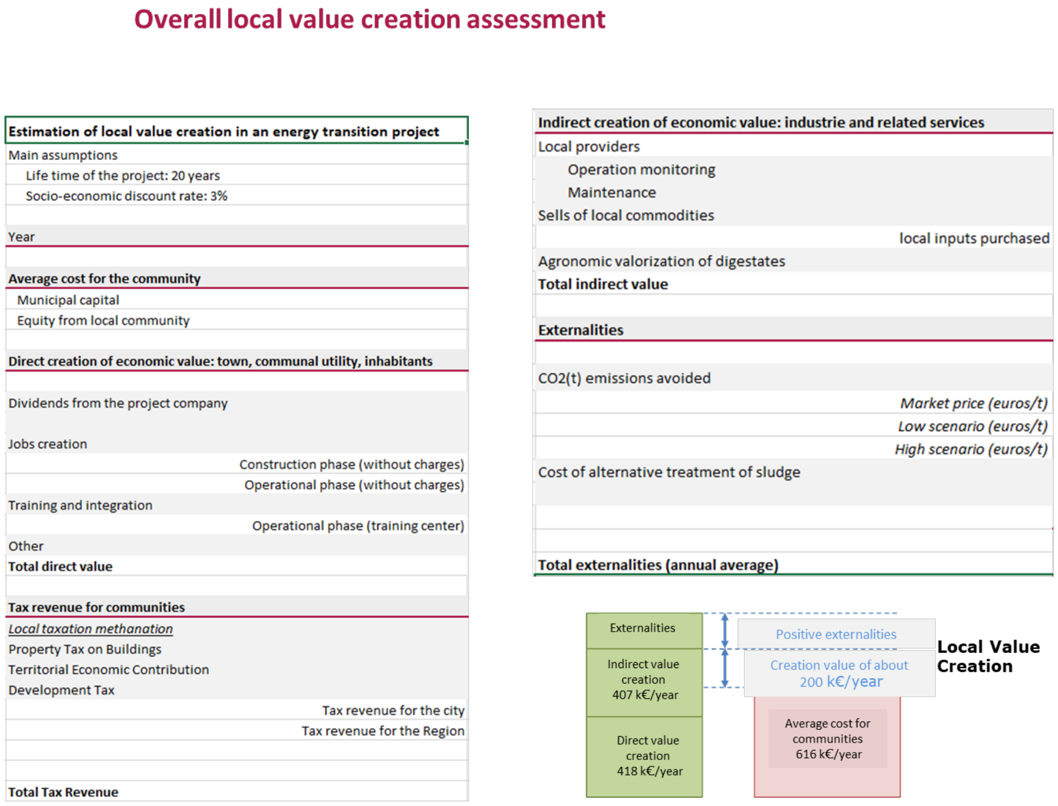


Figure 43: Extract from value creation assessment tool (source: Tilia)

As previously mentioned, following the DH system's upgrade, the newly created local utility started offering **energy efficiency services** following an ESCO[30] model (upgrade of the urban street lighting, energy management for the city administration, …), creating additional value for the community.

Regarding consumer empowerment, the DH grid has **individual metering at apartment level**, and billing is part of the rental costs. Consumers are therefore aware of their consumption. Overall, there is a good satisfaction of clients.

The connection to the DH grids lowers the Primary Energy Factor, which also means that less renovation of the thermal envelope is needed to reach national standards.

[30] Energy Service Company

6.7.7. Prospects

The transformation towards lower temperature systems is currently not possible due to the existing **heat emitters** in the buildings. For the time being, the DH company is concentrating on the near future as the current CHP feed-in tariff will come to an end and new customers could be expected due to the increase of natural gas price. As a consequence, **a new CHP** replacing the current one might be considered in a first step.

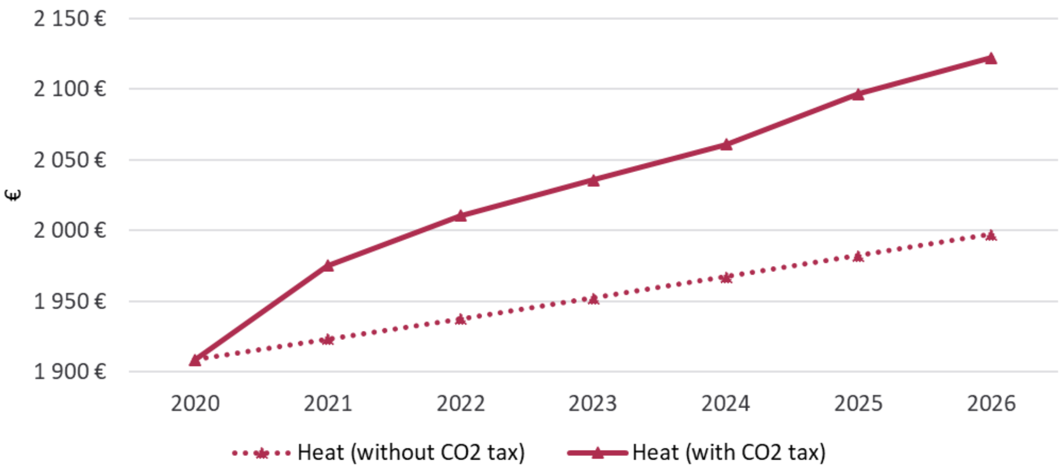


Figure 44: Expected impact of CO2 taxes on full annual cost of individual gas heat supply for a typical household in Querfurt (source: Tilia)

As shown in Figure 44, **the future taxes on CO_2 will have a clear impact on the cost of gas heat supply, increasing the competitiveness of the biogas DH grid**. Indeed, the full annual costs of DH are expected to remain between 1900 and 1950 EUR/y in the showed period, and **the integration of RES contributes to price stability**.

Depending on those taxes, the next DH supply solution may be to integrate **biomass** energy (wood), as **geothermal** energy or **solar** thermal energy would require lower temperature systems (heat emitters) or the use of high-temperature heat pumps (able to reach 85°C) which are currently not economically viable and not supported by financial aid schemes in Germany. The DH company is also studying the opportunity to integrate **heat pumps coupled with solar photovoltaic** to supply the DH grid. There are no waste heat sources in the area.

6.7.8. Conclusion

The case study of Querfurt illustrates how a **DH network** can be **modernised and decarbonised while maximising local value creation**. It also shows the synergies' potential between DH and agriculture through local biogas production.

The following **key enablers for RES integration** have been identified and could be replicated in other communities.

i. **The national support schemes for renewable heating** (biogas CHP feed-in-tariff, CO_2 taxes…), enabling the financial viability of decarbonisation projects and supporting the competitiveness of DH against alternative fossil solutions (in this case natural gas).

ii. **A fruitful public-private collaboration**, in this case through a **performance-based** service contract strengthening the incentives to reach the targets commonly agreed between the public party (DH operator) and the private partner (Tilia), namely: decrease of DH price, increase of sales, reduction of CO_2 emissions and local value creation.

iii. **A pragmatic, long-term and inclusive approach,** putting **price competitiveness and local value creation at the core of the strategy.** The design of possible new projects was undertaken in close connection with local stakeholders, some of which are also part of the solution (e.g., the agricultural cooperative feeding and co-owning the new biogas plant).

iv. **A complete benchmarking of those potential projects and solutions** by the private partner **based on economic, environmental, and social welfare criteria** established with the municipality (owner of the DH grid).

v. **The proximity of the DH system to agricultural facilities**. This allowed to produce local biogas and to integrate it into the DH system in a profitable manner, while securing the feedstocks for biogas supply and the offtake by the DH system through a long-term contract between the biogas plant and the DH operator.

vi. **The creation of a new municipal DH company**, bringing a new lever to the municipality to implement its energy strategy: higher revenues, possibility to offer new services, creation of local employment…

vii. **A balanced share of profits** between the DH operator and the community. For instance, a 50% joint venture was created between the municipal housing association and the **local agriculture cooperative** feeding the new biogas plant, and the business model includes a moderated target margin of 3-5% for the DH operator, above which the **profits are shared with the consumers via tariff reductions**.

viii. Finally, the modernisation project fostered the **continuous improvement culture** of the DH operator, and its willingness to continue decarbonising its energy mix by seizing opportunities as long as these are economically viable.

6.7.9. References

- 2016 Fernwärmegesellschaft Querfurt mbH, "Energy efficiency increase Querfurt: Retrospective and Prospects"

6.8. Case study Aranda del Duero (ES): switching from fossil heating to renewable DH in an urbanised environment

6.8.1. National context

Spain is an emerging market for DHC systems. Heating in Spain is dominated by fossil-fuel sources (mainly natural gas) and individual solutions, while DH represents less than 1% of the market, and is mainly fuelled by renewable energies (mostly biomass). The first large DHC system in Spain was **established in 2004** in Barcelona (Districlima Barcelona[31]), following a concession model (PPP).

Table 14: Key Facts for DHC in Spain

DHC in Spain - Key facts		
Regulation	Regulator / Supervision authority	• DHC is not a regulated activity in Spain • Other authorities: National Commission on Markets and Competition (*CNMC*)
Regulation	Role of municipalities	• Support DH through urban and energy strategies, connexion of public buildings
Regulation	Ownership (in terms of capacity, 2019)	• Public-Private Partnership (PPP) (33%) • Private (35%) • Public (32%)
Incentives	DHC support schemes	• Premium tariff scheme for CHP electricity • Guarantees of Origin for renewable electricity • Obligation for new industrial plants or DH network with a capacity over 20MW to analyse the possibility of CHP • CO2 savings showed in building energy labelling • European structural funds (ERDF)
Market	Total DHC sales to customers (2017)	• Heating and cooling: 1 102 GWh
Market	Main clients (in terms of sales, 2017)	• 33% residential, 49% tertiary, 18% industrial
Market	Main operators (in terms of turnover, 2017)	• Main private: Veolia, Engie, San José, Sacyr, REBI, Hunosa, Ferroser

Today, new DHC systems are being developed mainly under totally public or **private** initiatives. This case study illustrates the latter, a DH system developed through an **ESCO model (Energy Service Company)** that is being replicated in several **small to middle-size Spanish communities**.

6.8.2. Local context

Aranda del Duero is a 32,800 population town located in the region of Castilla y León. This Region has the largest forest biomass resources in Spain, covering 51% of its surface, and has established a **regional strategy to support** the **biomass** industry and a higher use of biomass in energy production and consumption, as a means for economic growth, sustainable development, forest fire prevention, and to face the demographic challenge associated with population decline and aging[32]. Indeed, the region is **active all along the biomass value chain** (from resource management to transport, process, pellet and boiler production, and associated services).

This regional strategy includes the **support to developing DH systems fuelled with biomass**. In 2020, there were 65 DH systems in Castilla y León, representing 9.8% of

[32] The regional measures to fight climate change were approved in June 2020 (link to BOCYL, in Spanish)

the national installed capacity, developed both under public and private schemes. The case of **Aranda del Duero**, whose **new DH grid** entered operation in 2019, is the **first one in the country combining biomass and industrial waste heat recovery**.

Table 15: Key urban indicators for Aranda del Duero

Aranda del Duero City		
Statistics (2019)	Population	32 856
	Demographic trend (2015-2019)	- 0.02 %/year
	Density	258.1 inhab./km²
	Housing (number of dwellings)	?
	Housing in multi-flats buildings	?
	Heating degree days	2 240
Regulation	Building regulation (national)	Regulation of Thermal Installations in Buildings (2007): obligation to analyse the possibility of connection to DH for every new building over 1 000 m². No zoning possible.

Aranda del Duero has a **continental climate**, and most of its population is heated through **central heating solutions, mainly fuelled with gas and oil.** As many of those fossil-fuelled central boilers were reaching their economic end of life, developing a new DH system appeared as an opportunity for the **private project promoter, REBI**[33], which is part of the Amatex group[34], specialised in biomass. REBI had already developed other biomass-based DH systems in the Region (Soria, Ólvega) and in the neighbouring region Castilla la Mancha (Guadalajara).

The support of the municipality and the region was essential for the DH project's development. The former was needed to obtain the permits and authorisations required to occupy the public space, in exchange of a local fee corresponding to 1.5% of the DH sales. The project was aligned with the regional strategy mentioned above, and the region is also an equity holder of the regional asset company (cf. Section 6.8.3). Indeed, the biomass used by the DH grid comes mainly from the region (forest waste and management resources, processed to produce wood chips fuelling the DH boilers). Moreover, the City Council established an **obligation of renewable energy supply in some new urban developments,** which brings interesting opportunities for the DH grid.

The objective of the DH grid is to supply around 5,000 residential buildings and 30 public buildings by 2024, reaching between 15,000 and 20,000 end users through a 15 km grid supplying 45 GWh. This would represent 50% of the total potential market (**multi-apartment buildings with central heating** outside the historical city centre), and a reduction of 11,000 ton of CO_{2eq} per year. At the time of writing this report, the market share was 9.5% of the identified potential, and **DH is highly competitive against its alternatives** as the DH operator ensures at least 10% price reduction with respect to existing fossil solutions (cf. Section 6.8.4).

[33] https://recursosdelabiomasa.es/
[34] https://amatex.es/

6.8.3. Presentation of the DH system

The DH system in Aranda del Duero[35] aims at enabling a **city-scale fuel switch to RES** in heating, and has been developed under a **private scheme** (ESCO model). The map of the DH grid and key figures are presented below.

The first discussions on the project started in 2016. Following a development phase of around 3 years, the DH system entered operation in September 2019, with an **initial supply 100% based on biomass**. During the development phase, the opportunity of recovering industrial waste heat from a nearby factory of a tyre manufacturer (Michelin) was identified. This **waste heat is recovered and used for DH** since November 2019, becoming the **first industrial waste heat recovery for DH in Spain**.

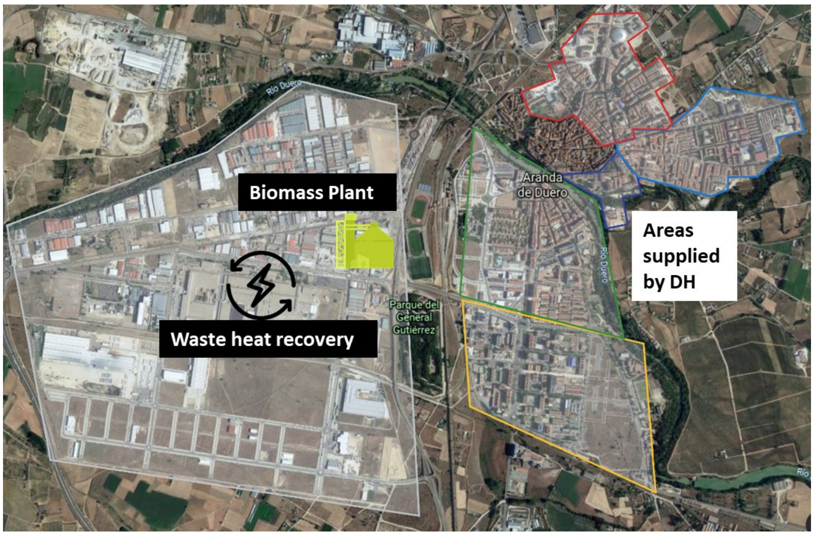


Figure 45: Map of the DH system in Aranda del Duero

Table 16: Key facts and figures Aranda del Duero (2020)

Key facts and figures	
DH market share	9.5 % of compatible buildings in the city
RES and waste heat share	100 %
CO_2 emissions (heating)	0 kg/MWh
Installed capacity	24 MW
Energy production	5.4 GWh/y
Km network (double-pipe)	15 km

Today's **production capacity** is therefore as follows:

- 2 biomass boilers, for a total of 12 MW;
- Waste heat recovery from an industrial facility (CHP unit) providing additional 12 MW.

A **thermal storage** tank of 4,000 m^3 (ca. 100 MWh) to optimise the production is under construction, able to store energy from the biomass boilers and also waste heat. It will enter operation in the 2021-2022 heating season.

The above production covers both base and peak loads, **using biomass and waste heat to meet the demand** (designed to use around 50% each source, but operated to maximise waste heat use). However, when switching from fossil-fuel based central heating to sustainable DH, **the DH operator offers to maintain the previous gas or oil boilers**, which could supply the building in the unlikely case of unavailability of the DH grid, as well as the DH grid if needed (reversible operation mode). This option has not been used since the commissioning of the DH grid, but is rather used to comfort clients on their supply switch, as part of the business model in place (see Section 6.8.4).

At the end of 2020, connected buildings included **8 multi-apartment buildings, a school and a public swimming pool** (5.4 GWh/y in total).

[35] https://reddecalordearandadeduero.es/

6.8.4. Governance and business model

Governance

The project promoter has followed a similar model to develop its DH projects in the different regions where it operates, organised around two companies:

1. A **regional company** developed through a **PPP model**, which owns the DH assets and undertakes the investments. This company recovers the investments through the concession payments of the project companies. In the case of Aranda del Duero, this company is called "Biomass heating plants in Castilla y León" (**CCBCYL**[36] in Spanish), and has the following shareholder structure:
   - 35 % owned by the Region of Castilla y Leon,
   - 65% owned by REBI, which is the project development partner.

2. A **project company** or Special Purpose Vehicle (**SPV**), specific to each DH grid, which takes the development and operational risks, and operates the DH infrastructure owned by the regional company paying in exchange a concession canon. In this case, the SPV is called "DH grid of Aranda del Duero" and has a **private ownership**, with a shareholder repartition as follows:
   - 80% Suma Capital EE Fund II (infrastructure fund)[37],
   - 20% REBI.

RED DE CALOR DE ARANDA DE DUERO

Rebi
RECURSOS DE LA BIOMASA

The DH grid is operated through a **Build-Operate-Transfer (BOT) model**, where the project sponsor and ESCO, REBI, has a 5-year BOT contract with the DH company (SPV) to promote the DH grid and manage its construction, operation and sales. REBI is therefore in charge of contracting the energy supply: local biomass sourcing within the Amatex group, and industrial waste heat through a bilateral contract with the local tyre manufacturer.

REBI's business model

The business model in place is highly innovative and based on a private initiative. Unlike concessions that can be found elsewhere in the country (in Barcelona e.g.), REBI's DH systems are developed as private projects and are regulated by general market laws only.

It was developed as a response to the difficulties experienced by the biomass sector following the economic and financial crisis of 2008. The Amatex group decided in 2011 to create an energy services company, REBI, to develop **DH grids using the Group's biomass**. The principal pillars of REBI's business model are the following:

- The target market is **small to medium cities** in the regions where Amatex has biomass production facilities (Aragón, Madrid, Castilla y León and Castilla la Mancha) or close to these, with continental climate and a **heating market**

[36] CENTRALES DE CALOR CON BIOMASA DE CASTILLA Y LEON, S.L.
[37] https://sumacapital.com/en

dominated by centralised fossil-fuelled boilers (compatible with DH). **Only urbanised areas** are sought.

- Following an in-depth heat market study proving the interest of a DH supply, REBI discusses with **local and regional public authorities** seeking for their support.

- The **services** offered include district heating and domestic hot water supply. REBI can also provide free of charge regulation services on the secondary grid (on the building side), to adapt the supply to the external temperature or to the demand, and by doing so optimise the **system's efficiency**. It is developing an offer including both thermal rehabilitation and connection to DH (cf. Section 6.8.6).

- Price competitiveness is key. The DH operator offers its clients **a minimum of 10% discount in their energy bills** with respect to their existing heat supplier, as well as the **maintenance of the existing heating facilities** at building level (gas or oil boilers).

- **Supply contracts with clients** are signed as the DH network develops (**at least 5-year** duration, typically between 5 and 10 years). REBI therefore takes the **commercial risk** of the DH grid development, which is mainly mitigated by the tariff structure (guaranteeing 10% discount and therefore price competitiveness), and ultimately backed by the SPV. These contracts include **2 tariff options**, further developed below, and the DH operator invoices the end users on a monthly basis.

This model was initially implemented in a pilot DH grid in Ólvega (3,600 inhabitants) in 2012, then scaled up in Soria in 2015 (89,500 inhabitants), where Amatex headquarters are located. Replicating the Soria model, the DH grids of Guadalajara (259,000 inhabitants) and Aranda del Duero entered operation in 2019, the latter integrating for the first time industrial waste heat recovery, and several other projects are on the pipeline (cf. Section 6.8.7).

Negotiating Third Party Access (industrial waste heat)

The biomass production facilities of the DH grid are located in an industrial area of the city, close to the **tyre manufacturing factory** where the waste heat potential was identified. This factory is supplied by a CCGT plant producing combined heat and power, and owned and operated by the utility company Energyworks Aranda (Iberdrola Group[38]).

Following **bilateral negotiations** with this utility company, a **10-year contract (extendable)** was established between the DH operator and Energyworks Aranda for the supply of 50% of the DH demand, or higher. This contract includes a fixed price for the first 2 years, and another fixed price for the following 8 years, indexed to the inflation.

[38] www.iberdrola.com

The investments needed to recover the waste heat were around 1 MEUR, financed by the regional asset company.

Aranda del Duero DH Prices and Tariffs

The **DH grid investments,** to be undertaken over 5 years, represent a total amount of 15 MEUR. These are fully recovered through the energy sales, and **do not benefit from any investment subsidy or fiscal advantage** (VAT is 21% for all heat supply options). The DH business is profitable (positive net result), and sales keep growing.

As per today, REBI's strategy does not require to make pass-through tariff structures (i.e. the revenue structure does not exactly match the cost structure). There is no connection fee during the development phase, and clients can choose between **2 tariff options, both more competitive in price than their fossil alternatives** (see Figure 46 below).

a) Discount 10% Tariff (fixed and variable terms), ensuring clients a fixed 10% discount with respect to previous fossil-fuel supply, being updated monthly or quarterly according to oil and gas prices respectively (the fixed term, which depends on the contracted capacity, is actually also adjusted to ensure the 10% discount).

b) Stability Plan Tariff (fixed and variable terms), proposing a fixed tariff throughout the year, updated annually based on inflation (inflation + 1%). On an annual basis, the fixed term corresponds to around 10% of the bill.

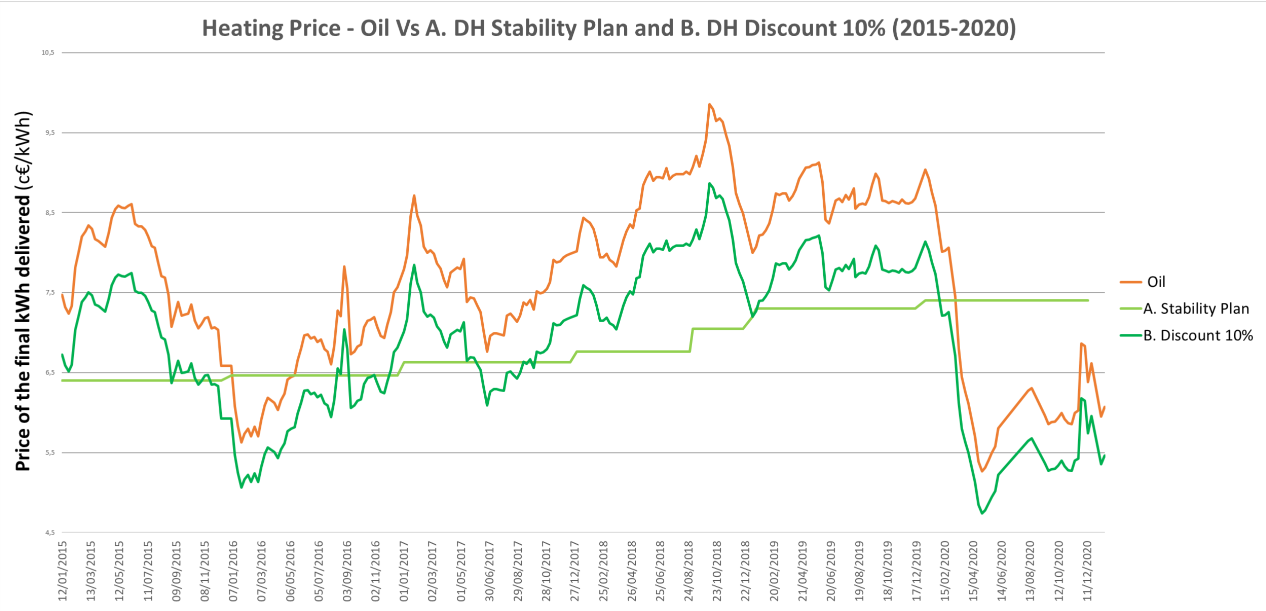


Figure 46: Price competitiveness of the DH with respect to oil boilers (source: REBI)

The average price since the grid's commissioning is **78.65 €/MWh** (incl. 21% VAT). At the moment, most of the clients opted for the Discount 10% tariff. For a typical residential client (multi-apartment building), connecting to the DH grid results, overall, in

25-30% reduction of its heating bill (i.e., saving 10% of energy payments + 100% of investments in gas/oil boilers, with a 15-year lifespan).

Optional **services** include regulation of the secondary network in buildings, resulting in higher efficiencies and a reduction of the energy bill for the end users (lower volume). Besides, REBI is developing a **combined offer for thermal rehabilitation of buildings and connection to the DH grid** (see Section 6.8.6).

6.8.5. Use of RES and waste heat

The objective of the DH operator is to cover all the city of Aranda del Duero with one single DH network fuelled with low-carbon energy sources. To do so, several technical, economic and organisational aspects have been considered, from buildings' requirements and energy production, to the efficient management of the construction works in an urbanised environment, minimising nuisance.

Connecting buildings

Most of the currently connected buildings are **residential multi-store buildings**, with an average heating consumption per household of 8,000 kWh (incl. domestic hot water), and 10 kW contracted (cf. Figure 47 below). The DH supply temperature requirements are **75-85°C in winter, and 65°C in summer**.

Half of these buildings were previously fuelled by natural gas, and the other half by oil. These **previous fossil-fuel boilers are maintained in the buildings, and their O&M is completely taken over by the DH operator**, which also installs the DH heat exchanger in the building's boiler room with no cost for its clients.

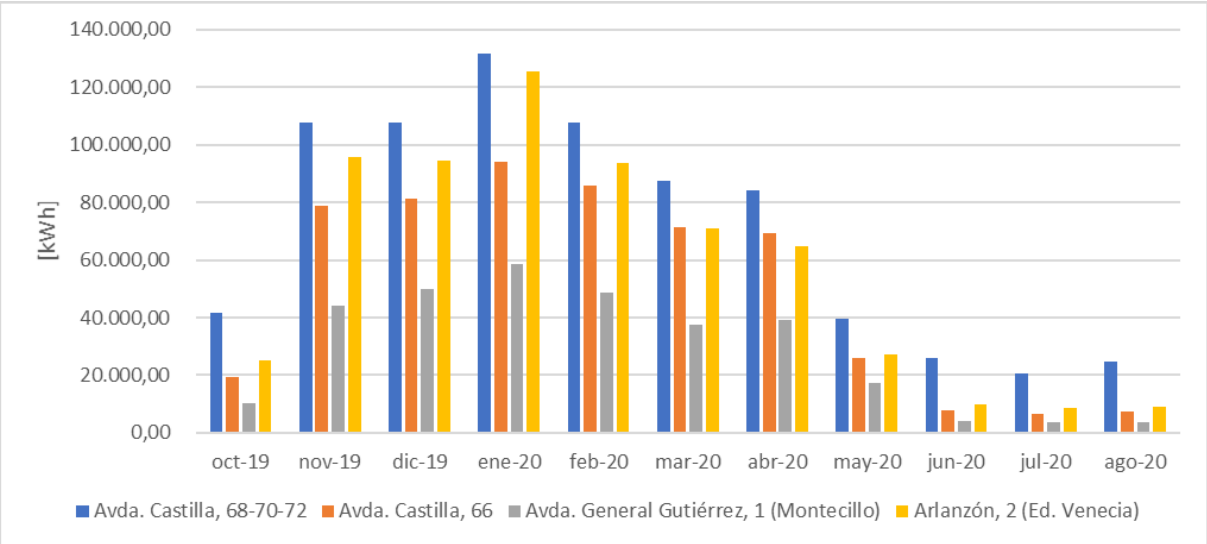


Figure 47: DH demand of 4 of the residential clients (source: REBI)

Combining biomass and industrial waste heat to optimise the DH production

Aranda del Duero's DH grid operates at a **temperature regime of 87 / 73 °C** (supply / return in winter[39]). The grid is equipped with optic fibre, delivering **real-time data to the control unit** to ensure a smooth and optimal operation, and has not experienced any supply interruption since its commissioning.

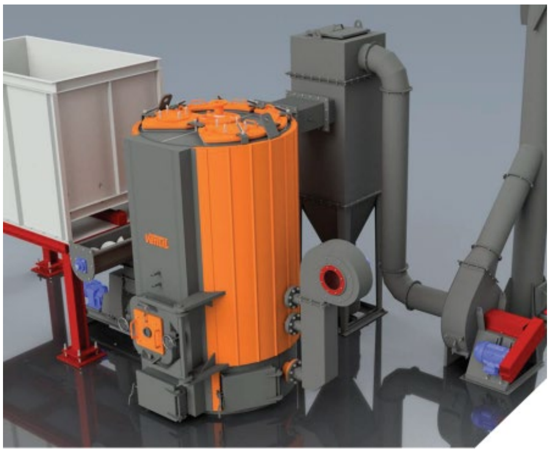


Figure 48: Biomass boiler (source: VENTYL)

Following the business model explained above, **biomass is the cornerstone of the DH grid**, complemented by additional industrial waste heat. The biomass boilers used have **85% efficiency**, and are fuelled by **wood chips** produced mainly in the region by Amatex. Flue gas particulates are filtered using a cyclone filter (pre-filtering) and a bag filter.

The **thermal storage tank of 4,000 m³** under construction at the time of writing this report will enable to optimise the heat production **to maximise the use of waste heat**, bringing also **higher flexibility** to the grid, as this tank can store 100 MWh, equivalent to 8 hours of a 12 MW biomass boiler production.

Figure 49 : Waste heat exchanger (steam/water) at the tyre manufacturer plant (source: REBI)

Finally, **industrial waste heat completes** the production mix, providing more than 50% of the DH supply (**70% in 2020**). Waste heat is recovered from a 33 MWe / 75.5 MWth **CCGT CHP** unit in form of **steam**. Up to 15 ton/h of steam at 4.5 bar are recovered through a heat exchanger of **90% efficiency** (Figure 49).

The heat recovered by the DH system was previously untapped, released into the environment through cooling towers. The DH grid enables to recover **15 to 40 GWh/y** of waste heat and use it for meeting buildings' energy demand, even if at the time of writing this report the actual use is 3.6 GWh/y.

The scheme is interesting for both the utility company operating the CHP unit at the tyre manufacturing site and for the DH operator, as both reduce their operating costs thanks to it, and it is also a new source of revenues for the waste heat producer. The heat recovery represented ca. **1 MEUR investments** (mainly heat exchanger and

[39] Summer temperature regime is 75/65°C

pipeline to the energy plant). These were undertaken by the regional asset company (CCBCYL), in exchange of a heat supply for **at least 10 years** at the agreed technical and economic conditions.

Biomass and waste heat production are highly complementary, as shown in Figure 50 below and following this first experience REBI is willing to replicate the scheme in other DH grids (e.g., in Soria, where a similar heat recovery facility is under construction). The DH operator is actively looking for additional optimisation levers, as further explained in Section 6.8.7, allowing the grid to remain competitive against alternative heating solutions.

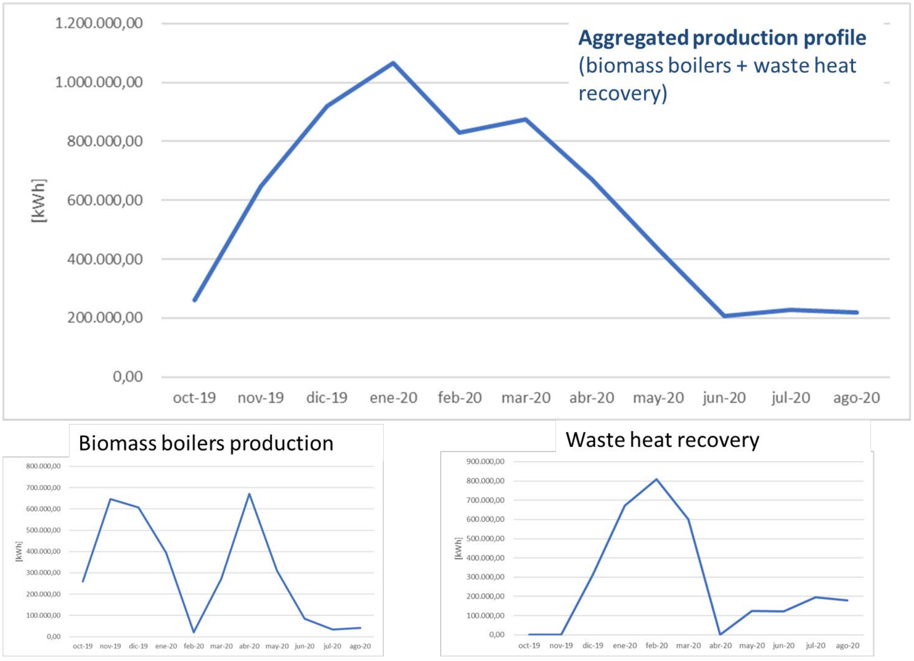


Figure 50: Production profile of the DH grid of Aranda del Duero (source: REBI)

Minimising DH works' nuisance

As the DH grid is being built in an urbanised environment, minimising the construction works' nuisance was of utmost importance. Indeed, the building permit indicates a maximum length of open trench. This constraint has been integrated into the construction planning, and pipe trenches are closed as soon as the pipes are installed. For each connection, REBI has paved the whole municipal street to encourage DH connections, as it does in all its projects.

Figure 51: DH construction works in Aranda del Duero (source: REBI)

Indeed, **local political resistance to DH works is often a barrier for developing new DH systems in urbanised areas**. In the case of Aranda del Duero, the typical duration of 100-150 m pipe works in a street was 2 weeks, and both the municipality and consumers deem the environmental and economic benefits are worth it.

6.8.6. Sector integration approaches and local value creation

The new DH grid is **enabling a deep decarbonisation of the city's heat demand through sector integration**:

- The current facilities are connecting the building demand with the **local industry,** through the waste heat recovery and the use of local biomass produced in the region, maintaining and creating local jobs (see below).

- The arrival of the DH system has also brought awareness on **synergies between building infrastructure and sustainable heating solutions**, and on the opportunities brought by DH. This has led to an increased cooperation with real estate promoters and the municipality in new districts under development, to build **efficient buildings compatible with DH** (secondary network, temperature regime…). The DH operator is also working on a common offer **combining thermal rehabilitation of buildings and DH connection,** which should enable buildings to reduce their energy consumption by around 40% and to substitute their current fossil fuel supply with decarbonised DH in the frame of an urban renewal plan affecting 1000 households, eligible to EU structural funds (ERDF). This comprehensive approach to energy renovation has already been implemented in some buildings, like the one in Figure 52.

The new DH grid is also proving to contribute to **local value creation:**

- The heating and domestic hot water **energy bill** of the connected buildings has been **reduced by at least 10%**, with the possibility to opt for a "stability" tariff providing a **stable price, independent from fossil fuels price fluctuations;**

- The direct and indirect **local employment** created is estimated at **40 FTE;**

- The DH company pays annually 1.5% of its sales to the **City Council** for occupying the public space with its DH pipes, and the construction works are also a source of revenues for the city (e.g. permits);
- **CO_2 emissions** have been already reduced by 1,600 ton/y[40], and once the grid is fully developed this figure is expected to go up to 11,000 ton/y.

- Finally, the DH project contributes to increasing the attractivity of the city, as well as its urban innovation activities.

Figure 52: Residential building before (left) and after energy renovation (source: REBI)

The DH operator uses state-of-the-art **digital solutions,** such as optic fibre to control and monitor consumption and production feeding the grid's SCADA system. This allows the DH operator to manage the demand and to increase energy efficiency, and this service will also be offered to its clients in the near future to allow them to take more informed energy decisions and **access their consumptions** on the DH website and mobile app. **Leak sensors** are also installed in the pipelines to detect heat losses.

6.8.7. Prospects

The DH system being at its first years of operation, the main projects concern grid **extensions.** As mentioned above, the DH operator aims at reaching 50% of the identified demand (**existing compatible buildings**) in 5 years. On top of it, some **new districts** are expected to be supplied by DH (2021-2022), as well as a new hospital (to be commissioned in 2026).

On the **production** side, the main opportunities identified are the following:

- The new thermal **storage** previously mentioned, which will be used for peak supply, cost optimisation and service improvement;
- Installing PV panels (100 kWp) within a self-consumption scheme, to reduce electricity costs (currently 12% of the OPEX) and decarbonise the electricity

[40] Methodology of the Spanish Institute for the Diversification and Saving of Energy (IDAE)

consumption. A first PV system of this type is already in place on the rooftop of the boilers' room, allowing to supply at least 25-30% of the needs, and up to 70% under certain conditions (midday, 100% waste heat operation);

- New **Power-to-Heat** solutions, namely heat pumps and absorption machines, the latter mainly to provide **cooling** to the tyre manufacturer from its own waste heat;
- **Geothermal** energy, as there is the possibility to use 30°C geothermal resource at 1500-2000 depth. This is currently under study.
- In a longer term, integrating hydrogen solutions, to build on the opportunities arising from the national hydrogen strategy.

Finally, the DH system of Aranda del Duero is highly **replicable** in other similar Spanish cities, and REBI is working on developing new projects aiming at using industrial waste heat for DH supply (e.g., in León, Burgos and Valladolid).

- The main **barrier** encountered is the **lack of awareness of municipal technical teams** on DH and associated permitting procedures.

- Regarding potential **accelerators and enablers**, the DH operator highlights national initiatives like **fiscal incentives** (e.g. reduced VAT, as today all heating vectors are subject to 21% VAT in Spain), **investment subsidies** (e.g. through EU structural funds and national programmes), the introduction of environmental taxes for fossil-fuel heating solutions, or the recognition of the CO_2 emission rights, as well as **local initiatives** like the reduction of local real estate taxes for connected buildings.

6.8.8. Conclusion

The case study of Aranda del Duero shows a **successful example of city-scale heating decarbonisation in an urbanised environment through DH**, in an emerging DHC market (Spain) with almost no public support to efficient DHC. The identified KSF for this project are the following:

i. A **tailor-made and innovative business model** enabling to decarbonise H&C in urbanised environments, within a very competitive H&C market, and with very limited public support for renewable H&C solutions. This model is **highly flexible** and based on a **private initiative**. It results in a DH offer which is more competitive than its fossil-fuel alternatives, **despite the general lack of public support** (no financial support).

ii. **A private sponsor (REBI) willing to take the development risk and mobilising private and public funding** to undertake the needed investments. Inspired on DHC experiences in Northern Europe, Amatex, a producer and supplier of biomass chips and pellets (and the mother company of the energy services company REBI) decided to develop a **DH company to complete its activities all along the biomass value chain.** After proving the robustness of the solution in a pilot small community and in a medium city, other small and medium cities are willing to support this operator in developing sustainable DH systems in their territory.

iii. **Local political support from the city and the Region** was crucial to develop the DH grid. The project supports the region's strategy for a higher use of local biomass in energy production and consumption, and has proved to **create local value** (significant savings in the energy bill, additional revenues to the city council, local employment, reduction of CO_2 emissions…). The city is integrating DH in its **urban planning**, notably in the development of new eco districts and district renovation strategies.

iv. **Price competitiveness is key in such a competitive market.** DH is not only cheaper than its fossil fuel alternatives, but is also increasing the available solutions on the market. The DH operator is actively looking for cost optimisation possibilities to maintain its competitive prices.

v. The **quality of the service** is also essential, as DH is a new solution entering the local market, in a country dominated by fossil heating were DHC represents less than 1% of the heat market. Any quality issue would put at risk the reputation of the operator and even of the solution, and therefore the highest attention is put on client's satisfaction.

vi. To ensure a competitive and quality DH supply, an optimal production using local and decarbonised energy sources is in place. **Local biomass is used as the DH system cornerstone, to then progressively integrate other low carbon energy sources** (industrial waste heat, renewable electricity…) and thermal **storage** to minimise operational costs and continuously improve the economic and environmental performance of the grid.

vii. **The flexible and evolutive approach retained** by the DH operator is also contributing to its success. REBI is actively looking for optimisation leverages, like new energy sources to integrate (e.g. industrial waste heat, solar PV…), and for opportunities to improve its offer (e.g. linking DH connection to thermal refurbishment of buildings).

viii. Finally, **innovation** appears also as a key ingredient for the success of this DH project. REBI developed the **first industrial waste heat recovery** operation in the Spanish DH sector, valuing excess heat from a CHP unit that otherwise would remain untapped. This scheme is highly **replicable**, and Aranda del Duero's DH grid has also been a real-scale pilot proving the solution. Besides, the network contributes to **creating awareness of the benefits of sustainable DH** in a still emerging market, which could encourage policy makers at national and local levels to provide higher support to DHC to reach energy transition targets.

6.8.9. References

- 2021 REBI – Global presentation
- 2021 REBI – Tariff models

6.9. Case study Islington – London (UK): an innovative concept of waste heat recovery developed by a local public authority

6.9.1. National context

With about 12 TWh of DH energy consumption in 2018, **the United Kingdom is still a relatively small market for DH** in Europe. The Low Carbon Heat Roadmap 2020 has not been released yet but seems to focus mostly on individual solutions.

Thus, **the lack of regulation for DH sector is a key barrier** to the expansion of the UK heat networks market. At present, unlike other energy generation facilities and infrastructure, DH does not benefit from a regulated investment framework to help bringing down the costs of investment.

Table 17: Key facts for DHC in United Kingdom

DHC in United Kingdom - Key facts		
Regulation	Regulator / Supervision authority	• The heat networks market is largely unregulated. There is no regulation regarding ownership and operatorship • The Association for Decentralised Energy has set up a non-for-profit organisation called Heat Trust in order to provide industry standards and improve customers protection
	Role of municipalities	• Across the UK, some local authorities have used local development plans, concessions or zoning to direct heat network development
	Ownership (in terms of sales, 2018)	• Mostly Public Private Partnership
Incentives	DHC support schemes	• The Non-Domestic Renewable Heat Incentive (RHI) is supporting non-domestic RES-H installations (Aerothermal, Hydrothermal, Biomass, Geothermal, Solar thermal, and associated CHP) with a fixed amount per kWh produced which is payable for 20 years (not available anymore) • CHPQA is an energy efficiency best practice programme initiative. CHPQA aims at monitoring, assessing and improving the quality of CHP in the UK • The Heat Networks Investment Project provides £320m in capital grant and loan gap funding to public and private sector heat networks
Market	Total DH sales to customers (2018)	• Heating: about 12,000 GWh • Cooling: not reported
	Main clients (in terms of sales)	• Not reported
	Main operators (in terms of turnover)	• Veolia, Engie, Vital Energi, E.ON and EDF Energy

While DH systems in the UK are mostly concentrated in big cities and managed through concessions, Islington DHC system is a **relatively small network located in Inner London** (which hosts other DHC systems), **owned and operated by the London Borough of Islington.** It is therefore a good example of a local initiative managed by a public authority in order to develop reliable and efficient heating services. Overall, Islington DHC is a first-of-its-kind, as it recovers waste heat from the London Underground train network and uses low grade heat to supply a DHC network.

6.9.2. Local context


Figure 53: Aerial view of Islington borough (source: https://www.webbaviation.co.uk/)

The London Borough of Islington is located in Inner London. It covers a large area to the south which forms **part of central London**. Islington population has increased by one third since 2005 and has reached 242 467 in 2019.

Mostly made of housing (even if some offices are also found in the South of the borough), it is **the most densely populated district in the United Kingdom** (and one of the densest areas in the world), which makes it very difficult to find space for the implementation of infrastructures such as DH plants.

The building stock of Islington is relatively old, 60% of the stock having been built before 1919.

Table 18: Key urban indicators for London Metropolitan area

	Borough of Islington	
Statistics (2019)	Population	242 467
	Demographic trend (2017-2020)	+2,0 %/yr.
	Density	13 875 inhab./km²
	Housing	105 489
	Housing in multi-flats buildings	≈ 90 000 (86%)
	Heating degree days (with a reference temperature of 15°C)	2 800
Regulation	Urban regulation	Zoning set by the Greater London Authority (GLA) as priority zones for heat networks (no mandatory connection but obligation to assess the feasibility of connection)
	Building regulation (national)	Energy Performance of Buildings Regulations 2012, derived from the European Union directive

The **London Plan 2021**[41] is the Spatial Development Strategy for Greater London. It sets out a framework for how London will develop over the next 20-25 years and the Mayor's vision for Good Growth. Borough's Local Plans must be in 'general conformity' with the London Plan, ensuring that the planning system for London operates in a joined-up and coherent way, reflecting the overall strategy for how London can develop sustainably.

At the borough level, **Islington Council declared a climate emergency** on 27th June 2019, when a motion committing the council to working towards making Islington **net zero carbon by 2030** was unanimously passed. In its strategic document "Vision 2030: Building a Net Zero Carbon Islington by 2030"[42], Islington Council reminds that in 2020

[41] https://www.london.gov.uk/what-we-do/planning/london-plan/new-london-plan/london-plan-2021
[42] https://www.islington.gov.uk/~/media/sharepoint-lists/public-records/energyservices/businessplanning/strategies/20202021/20201209vision2030islingtonzerocarbonstrategy1.pdf

60% of its Greenhouse Gas emissions came from heating, and presents **DH as a key tool to provide sustainable and affordable energy, underlining the potential of waste heat recovery from London Underground and other sources.**

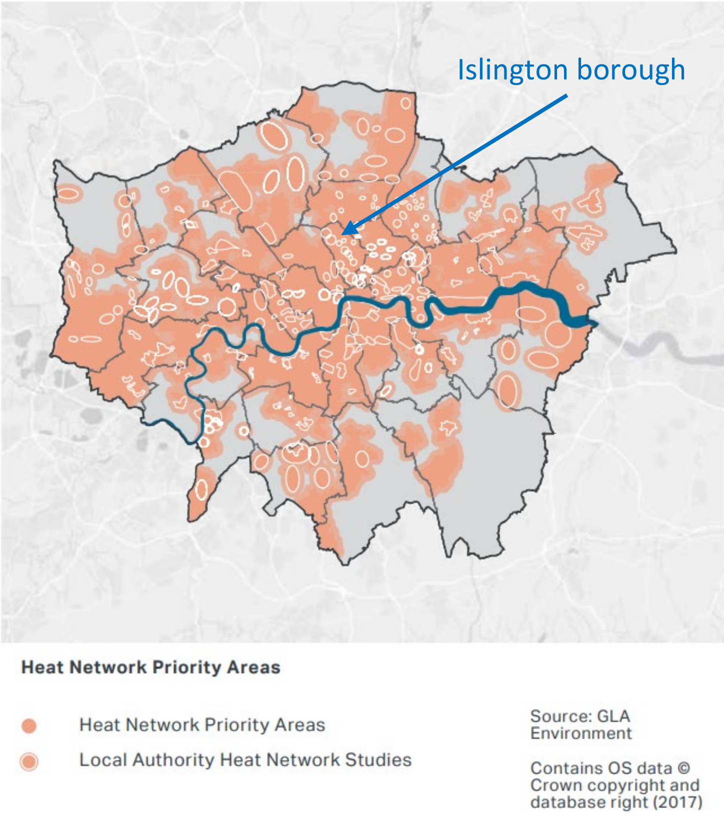


Figure 54: DH priority areas set by Greater London Authority (source: Greater London Authority)

Since the end of the 1990's, the **London Borough of Islington (LBI)** in the North-East part of London pursued a **decentralized energy policy**, aiming to supply customers with cheaper and greener heating. The first project resulting from this policy was the **Bunhill Heat and Power Network**, whose first phase was completed in November 2012.

The project received various awards and fulfilled its objectives, allowing the council to offer its tenants a **10% discount on their heating bills, reducing the carbon footprint of energy production while increasing the security of the energy supplied** (see section 0). This success paved the way to the extension of the network in phase 2 (main object of this case study).

The heating market in Islington is dominated by individual gas solutions (about 75%). Collective solutions such as communal heating (at the building or the estate scale) and DH (at the district scale) represent about 12% of the market. The remaining 15% is largely electric heaters (10%) and other various alternatives such as individual heat pumps.

Before the Bunhill Heat and Power Network began operating, buildings on the estates were heated by **gas-fired communal heating systems**. These systems were insular and not designed to be connected to a larger system. The **reliability of these systems** was a matter of concern for numerous stakeholders as the outage in one of the estates during Christmas 2000 had frustrated residents.

In addition, in the early 2000's, large private operations for communal heating systems were implemented throughout the country and resulted to high heating costs (the construction companies trying to save capital expenses by installing cogeneration plants that were cheap to procure but expensive to maintain and operate). As a consequence, **DH, which is often assimilated to communal heating, has a generally negative perception in the United Kingdom**.

Finally, the **complexities associated with the British building ownership landscape** (freeholders, tenants, leaseholders…) add difficulties and risks for DH developers. One way that the council deals with this is to get early into the process (land development), dealing with property owners directly rather than with the future end-users according to their ownership status.

6.9.3. Presentation of the DHC systems

The **Bunhill Heat and Power Network (BHPN)** is located in the London Borough of Islington in the North-East part of London. The first phase was completed in 2012 with the creation of the DH network, Bunhill phase 1, composed of 2 km of insulated pipework.

The Bunhill phase 1 network is supplied by a **2.2 MWth CHP engine powered by gas** and comprises a 115 m^3 thermal storage. The DH network supplies baseload energy, while peak and back-up capacities come from gas boilers located within each of the customer buildings (and operated by the buildings management).

All of the infrastructure is owned, operated and maintained by the LBI, with phase 1 **delivering heat to over 850 residential units (social and private housing) and a few commercial units (85% of the heat sales) as well as two leisure centres (15% of the sales).** Connection to buildings is done through heat exchangers in substations. Depending on the building's age, clients may have individual heat meters.

Figure 55: Key facts and figures of BHPN DHC network (phase 2)

Key facts and figures	
DHC market share	<1%
RES share	40 % of waste heat
CO_2 emissions (heating)	230 kg/MWh
Installed capacity	4 MW
Energy production	Phase 1: 5.9 GWh/y Expected max.: 19 GWh/y
Km network (double-pipe)	DHC: 2.5 km

The success of Bunhill phase 1 encouraged the council to extend the network to supply heat and domestic hot water to 550 additional properties on the King Square Estate and the recently rebuilt Moreland Primary School, as well as further private connections in the future.

A new Energy Centre was hence constructed in a second phase of extension with the ground-breaking idea to **recover waste heat from an underground train network through a 1 MWth heat pump**. This new Energy centre also includes 2 new CHP units of 300 kW each. The Bunhill phase 2 project forms with the Bunhill phase 1, the current Bunhill Heat and Power Network.

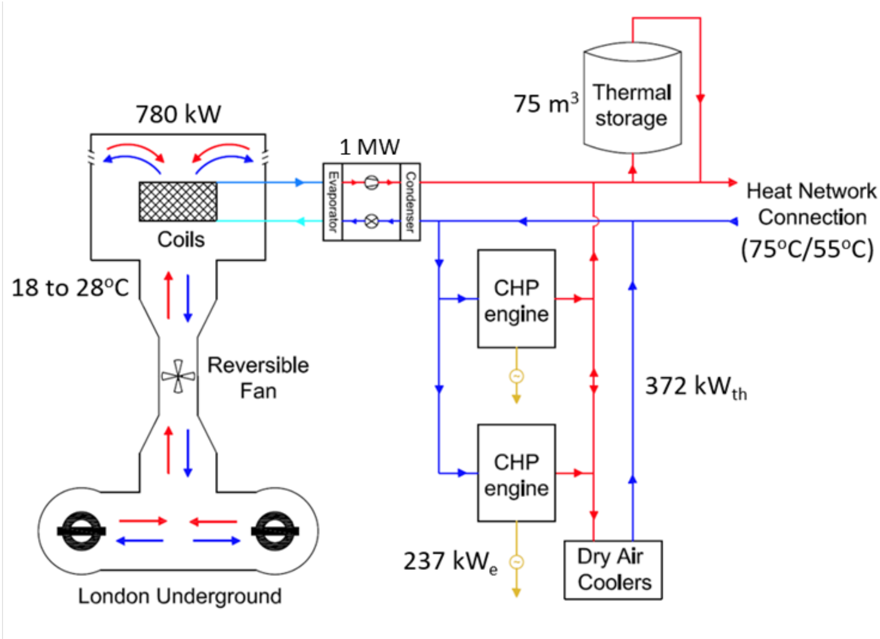


Figure 56: Technical scheme of the heat recovery from the London Underground (source: Heat from Underground Energy London, 2019)

With both phases completed (phase 2 is currently being tested and commissioned), the BHPN is expected to supply around 19 GWh per year, exclusively from CHP and waste heat from the London Underground ventilation shaft. With the second Energy Centre, the network has now more capacity than the number of buildings connected to the DH and can thus accommodate new connections.

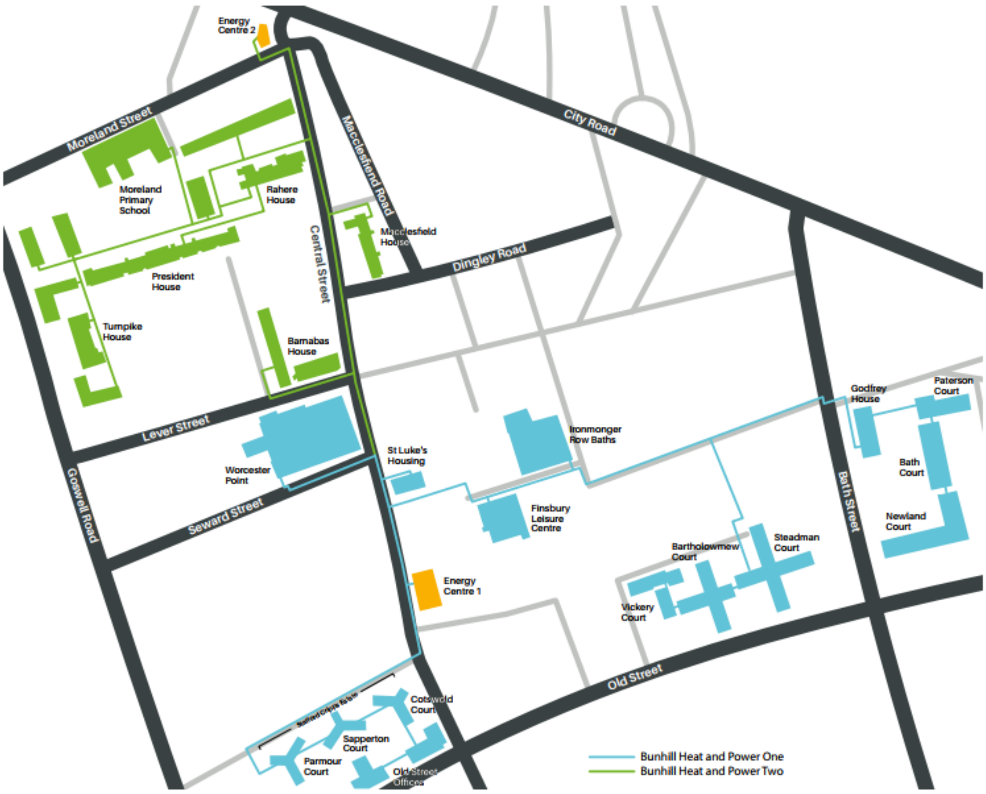


Figure 57: Map of the Bunhill Heat and Power Network (source: LBI Council)

6.9.4. Governance and business model

Governance and ownership

BHPN is fully owned and operated by the London Borough of Islington since 2012 (commissioning of phase 1). Phase 2 started in 2015 and is, at the time of writing this report, under testing and commissioning process.

Despite some changes of political parties at the LBI council, the project team managed to secure council support thanks to a close collaboration and to the accumulation of technical knowhow and organizational competence that continuously raised the level of trust towards members of the team.

The LBI project phase 1 and phase 2 were public funded projects, but much work involved actors from the private sector as well. More particularly, the Bunhill phase 2 project is an **outstanding example of collaborative work between Islington Council's Energy Services Team and a wide range of partners and contractors**, including:

- **Greater London Authority (GLA)**, which funded the early feasibility study for the project, coordinated London's overall involvement in the Celsius project[43] and brought together LBI council and Transport of London.
- **Transport for London (TfL)**, which upgraded its City Road mid-tunnel ventilation system to enable the capture and utilisation of waste heat from the Northern line tunnels. TfL is also carrying out further research to identify opportunities for similar projects across the "Tube" (London underground train network) as part of its Energy & Carbon Strategy.
- **Celsius project** (a European Union-funded project exploring low carbon innovation in DHC networks), which provided funding for the new energy centre and heat network expansion.
- **Several private companies** which managed the engineering studies, the architectural design and building permits, the design and construction phases, the testing and commissioning, and the overall strategic steering of the project.

Strategy and offer

BHPN provides **heat and DHW** to its customers, **as well as electricity** (from the CHP) to one council housing block and to TfL (for the underground fan). Providing cooling to TfL is also part of the plan in the near future (having the heat pump working in reverse mode during the summer).

Most of the customers today are part of LBI (public buildings, social housing…), but 2 private buildings have also connected to the DH network. Despite a reliable and affordable service, **BHPN offer is limited by the fact that it does not include peak and back-up capacities, which means that its customers have to keep their own heating system (and thus the associated maintenance cost and the necessary space for equipment)** to be able to respond to peak or back-up situations. Once phase 2 is commissioned, BHPN could evolve and propose additional capacities for peak and back-up in order to reach a bigger commercial target.

Heat supply agreements are usually made for 20-25 years, with the possibility to disconnect under certain conditions. Connection fees are negotiated on a case-by-case

[43] https://celsiuscity.eu/

basis. Invoicing is done quarterly for private customers (two housing blocks and 2 leisure centres) and for the council tenants.

In the UK, existing buildings are covered by the Heat Regulations and must have **heat meters at building level** (except if technical constrains show that this is not cost effective). In the case of new buildings, **sub-meters** are mandatory (typically installed at individual apartment level) as per building regulations. Heat cost allocators (approved at the building management level) shall be used for pricing/billing if there is no metering.

Financial model

The heating sector being unregulated in the UK, BHPN **tariffs are negotiated on a case-by-case basis** taking into consideration the technical features of each building (consumption, age, efficiency…). **LBI builds and adjusts its tariffs in order to meet the project break-even point** (total revenues equal total expenses), smoothing out the different investment costs (including connection fees) on the contract duration.

The **tariff** structure is differentiated:

- For tertiary customers (public buildings and leisure centres), it is made of one fixed component (indexed to inflation) and one variable component (proportional to the consumption and indexed to quarterly gas prices).
- For council housing, a global offer for heating and DHW is offered, including the DH supply as well as peak supply from collective gas boilers. This offer is managed by the Housing Department of LBI, which builds this specific tariff to meet the particular needs of social housing. It is based on a flat rate fee (proportional to the number of bedrooms). Council tenants get an additional 10% discount when their estate is connected to the Bunhill network (this discount does not apply to long-term leaseholders – who are, in the UK, people who have bought their flat from the council).

Phase 1 of the project was evaluated at about EUR 4.5 million and was fully covered by a grant funded by the London Development Agency (LDA) and Homes and Communities Agency (HCA). Part of these funds were made available by the GLA and the European Investment Bank's program ELENA[44] (European Local Energy Assistance).

Phase 2 of the project was initially evaluated at about EUR 4.6 million and funded by three grants: council resources (EUR 3.4 million), **the EU Celsius Programme** (roughly EUR 1.6 million) and a national grant for Energy Efficiency (EUR 0.5 million). LBI is currently also applying for the Renewable Heat Incentive (grant proportional to the MWh of energy being effectively supplied each year) in order to complete its funding.

As BHPN was a first-of-its-kind project with limited information and feedback on the technology for waste heat recovery from the underground train network, **phase 2 had to face various changes in design and planning, leading to increasing the investment costs**. The most impactful difficulties that can be quoted here are:

- the underestimation of trenching in Central London, where it is impossible to map precisely the different networks and underground infrastructures, which requires to always adjust the plans (sometimes very significantly) and coordinate closely with the multiple operators of these infrastructures,
- the complexity inferred by having to manage too many contractors (almost 40),

[44] https://www.eib.org/en/products/advising/elena/index.htm

- the contingency related to the third-party heat supplier TfL and the integration of their own engineering difficulties.

6.9.5. Use of RES and waste heat

Facing some political party's changes, different objectives were underlined for the project to accommodate the socio-political environment of the time. Among the objectives of the project are the **reduction of CO_2 emissions** and the supply of **reliable heat** with **stable and cheaper prices** than alternative heating technologies.

Today and thanks to a real change in attitudes, Islington Council's BHPN project plays an important role in Islington's commitment to reducing carbon emissions, helping lower heating bills, improving air quality and making London more self-sufficient in energy.

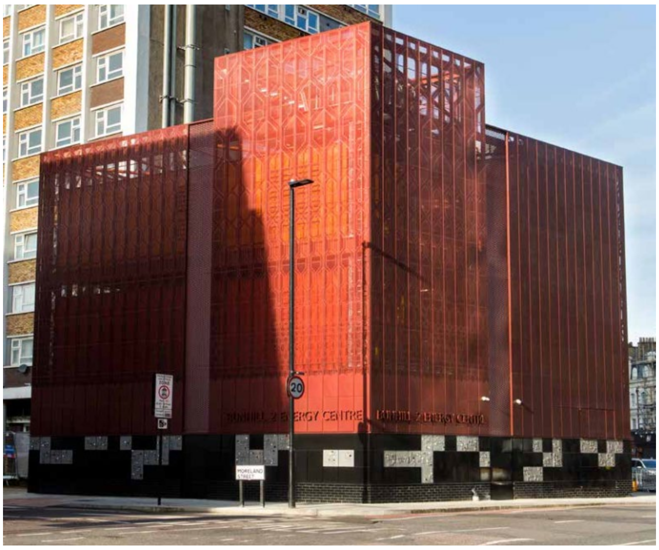


Figure 58: Phase 2 new Energy Centre with waste heat recovery from the underground train network (source: LBI Council)

For the phase 2 and the extension of the DH network of Islington, it was chosen to recover **waste heat from electrical transformers and ventilation shafts**. While technical issues related to the age of the electrical transformers eliminated this option, recovering waste heat on the Tube's ventilation shafts was further studied in cooperation with Transport for London's who was upgrading the London Underground ventilation. A careful joint work was required to ensure that all elements of the construction were fully integrated and taken into account on site.

BHPN is the **first operation in the world valuing waste heat from an underground train network** and using it to provide cheaper and greener heat to local homes, schools and leisure centres.

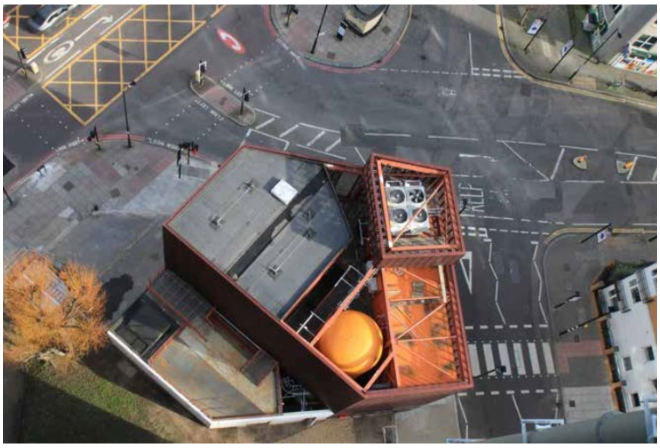


Figure 59: The new Energy Centre: during ground breaking over the existing vent shaft (on the left) and at completion (on the right) (source: LBI Council)

The system is based on a **1 MWth air-to-water heat pump** (COP of 4.2) that captures warm exhausted air produced by trains and machinery in the underground network. In order to increase the **heat output up to 1 MW**, the extracting fan in the ventilation shaft was upgraded to reach a 70 m^3/s flow instead of 30 m^3/s, at 22 °C in winter and 28 °C in summer.

In addition, **the fan in the ventilation shaft has the potential to be reversed in the summer to provide cooling to the Tube**, helping to make journeys more comfortable.

To accommodate the integration of this waste heat in the network, the supply temperature was reduced from around 90°C during phase 1 to 75°C during phase 2. The return temperature fluctuates around 55°C. This change in the temperature levels constitutes one of the technical challenges of phase 2 and explains some of the delays and budget overruns in the project.

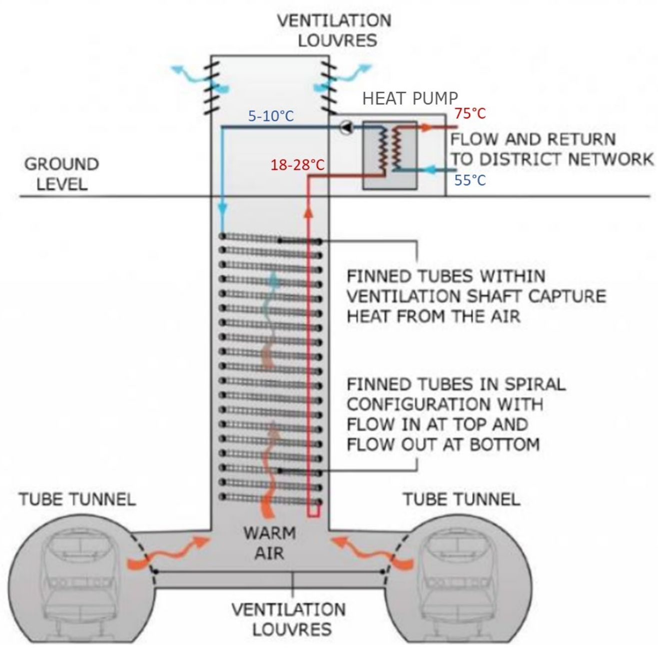


Figure 60: Illustration of the waste heat recovery from the Underground network (source: Greater London Authority)

All costs related to the ventilation shaft adjustments were supported by TfL, and LBI covered the cost of the heat pump and the whole Energy Centre. **Waste heat is provided to BHPN by TfL for free**, and BHPN is expected to provide cooling in summer to TfL for free in the near future.

6.9.6. Sector integration approaches and local value creation

The cooperation between BHPN and TfL for Bunhill phase 2 was a very successful partnership, as it originated benefits for local residents and the wider community:

- The two phases bring **cheaper and greener** heat to 1 350 homes;
- All Islington Council tenants connected to the DH network receive a 10% discount on their heating charges;
- The Bunhill phase 2 results in a reduction of approximately 500 tons of CO_2 per year;
- Adding a new Energy Centre increases the **resilience** of the network and the security of supply;
- Removing heat from the tunnel system in winter can help cool surrounding walls and hereby **lower overall temperatures during summer** and enhance users' experience;
- This new Energy Centre also helps London become more **self-sufficient in energy**;
- Electricity produced by the CHP is sold to TfL to run the fan extracting waste heat from the underground train network.

Besides BHPN, Islington Council is also helping thousands of residents facing **fuel poverty** with initiatives helping to reduce fuel bills in the borough such as the SHINE[45] network (Seasonal Health Intervention Network), or the Energy Advice team and Warmth on Prescription. Work to tackle fuel poverty and help residents save money on their fuel bill are priorities in the council's corporate plan "Building a Fairer Islington – Our Commitment 2018-22"[46].

LBI also provides energy advice over the phone and in person thanks to a network of **"energy doctors"** that inform their clients on best energy management practices. Furthermore, energy efficiency assessments are offered to clients to maximise the potential of each individual building. All those initiatives are funded by public authorities, public health as well as energy companies.

6.9.7. Prospects

Bunhill phase 2 project is a world first in recovering waste heat from an underground transportation network ventilation shaft. The successful partnership with TfL provides an **excellent basis that can be replicated across London and maybe other cities,** as many major cities across the UK and around the world have underground railway systems.

As a matter of fact, GreenSCIES[47] (Green Smart Community Integrated Energy Systems) is a community-based project located in another part of Islington borough. The project

[45] https://shine-london.org.uk/
[46] https://www.islington.gov.uk/about-the-council/-/media/8f2a74487b9f457e8c021b4b924c4baf.ashx
[47] https://www.greenscies.com/

was launched in 2020 aiming at delivering a detailed design for a 5th generation heat network. Using an ambient loop, the project would also recover waste heat from the London Underground and other sources like data centres.

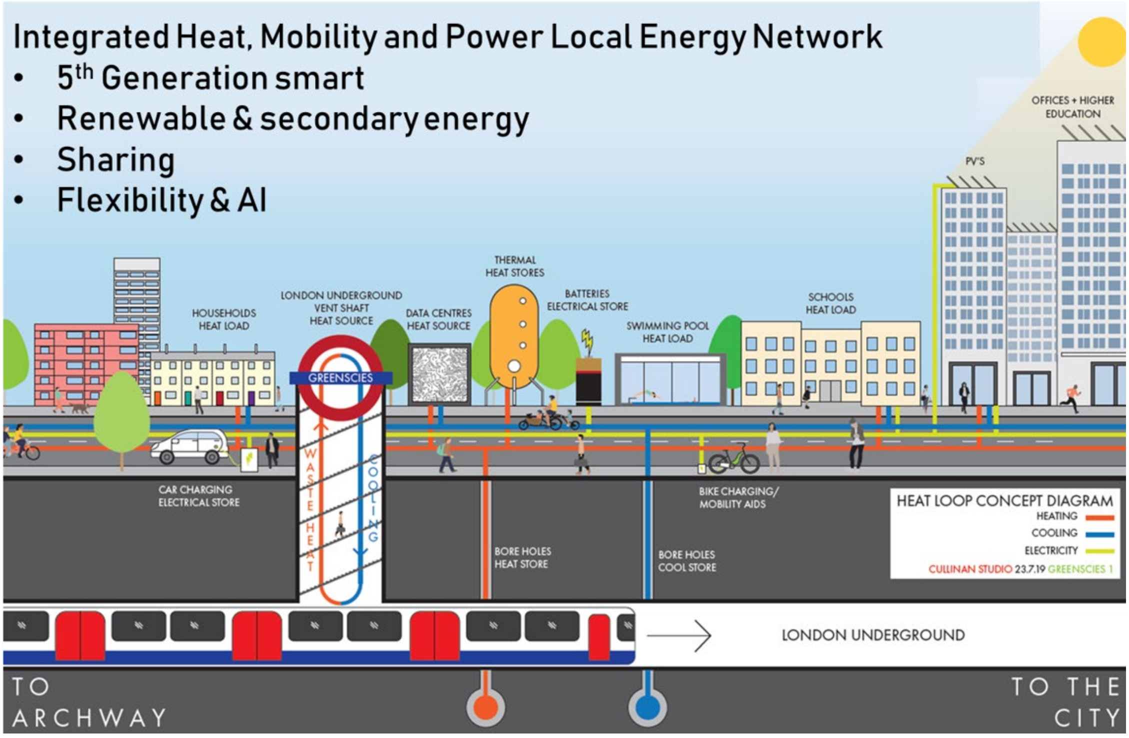


Figure 61: GreenSCIES, 5th generation heat network project (source: Greenscies)

Building and learning from the experience of Bunhill phase 2, Islington is looking for opportunities to **further expand the district heating network to connect more homes and businesses with waste heat sources**. With the objective for Islington to be Zero Net Carbon by 2030[48], the system is constantly exploring opportunities to integrate new technologies, for example, digital metering and heat management sensors.

6.9.8. Conclusion

Islington DH system is a good example of a **local initiative managed by a public authority** in order to develop reliable and efficient heating services. BHPN phase 2 project is a **first-of-its-kind as it recovers waste heat from the underground train network** and several studies are currently ongoing to implement this approach in other places in London and in Europe.

The key success factors identified in the case study are summarised below:

i. **The involvement of the London Borough of Islington and its teams**, the public entity owning and operating the DHC network. This was found particularly important here to facilitate the coordination with the multiple stakeholders (operators of the different infrastructures…) and partners (TfL, GLA…), and to secure customers (public but also a few private ones) in a country where zoning is not possible and where communal systems (to which DHC is often associated) still suffer from a relatively bad reputation.

[48] Vision 2030: Building a Net Zero Carbon Islington by 2030 (Link)

ii. **The efficient and open cooperation with TfL and the search for innovation**. In such an innovative project involving a third-party heat supplier, collective work is essential in order to meet the expectations of the different parties and to integrate the various technical requirements that can arise from both sides during the project development.

iii. **Obtaining national and European grants,** as the lack of regulation and financial support for DHC is still a key barrier in the UK for many projects. The capacity of LBI to get additional subsidies to finance some unforeseen costs of phase 2 is also one the challenges of this pioneering project.

iv. **The local climate strategy and the identification of DHC as a key tool to reach climate targets**. The waste heat recovery from the London Underground network will result in a reduction of approximately 500 tons of CO_2 per year.

v. **The integrated approach and diversity of the offer**, LBI also supplying electricity (as well as cooling in the near future) to its customers and/or partners.

vi. **The successful strategy to meet social needs**. LBI has managed to combine environmental performances and social accessibility: an adapted tariff structure is built for social housing (which is the main customers segment), a tariff discount is implemented for council tenants, and a comprehensive offer of energy advice is available for customers through a network of "energy doctors".

6.9.9. References

- Office for National Statistics, 2019
- Housing in London 2020, Greater London Authority Housing and Land, 2020
- The London Plan 2021, Greater London Authority, 2021
- Vision 2030: Building a Net Zero Carbon Islington by 2030, Islington Council, 2020
- Bunhill Heat and Power Network, Islington Council, 2020
- Celsius WP6 – Islington case study, Celsius project, 2014
- Heat from Underground Energy London, Lagoeiro, H.; Revesz, A.; Davies, G.; Maidment, G.; Curry, D.; Faulks, G.; Bielicki, J.. in Proceedings of the CIBSE Technical Symposium, Sheffield, UK, 25–26 April 2019

6.10. Case study of Graz (AT): decarbonization of a major DH system and improvement of the air quality in the city

6.10.1. National context

With the adoption in 2019 of the **Integrated National Energy and Climate Plan for Austria for 2021-2030**, Austria has recognized the key role of efficient DHC networks to achieve the full decarbonisation of the heating market. However, even though DH sales have increased by 5% between 2012 and 2017, the country has to face **extremely challenging market conditions**, where existing CHP plants and heating plants are currently hardly profitable to operate.

Table 19: Key facts for DHC in Austria

DHC in Austria - Key facts		
Regulation	Regulator / Supervision authority	• DHC is not a regulated activity in Austria • The Price Act frames the prices for consumers (setting a maximum price level)
	Role of municipalities	• Most municipalities own and manage their DHC network • Develop and review the local heat plans (including zoning), approve new projects, facilitate the link between the different stakeholders
	Ownership	• Large DH networks (about 25) in cities are usually owned by Municipalities and/or the energy utility companies (totally or partially owned themselves by the Municipalities) • Medium DH networks are owned by private operators (about 400 companies) • Small DH networks (over 3 000 systems) are owned by Municipalities • DC systems are almost exclusively owned by Municipalities
Incentives	DHC grid support schemes	• The National Corporate Environmental Support programme (UFI) promotes small-scale RES heating and cooling. All projects eligible for support are listed on the website of the settlement agency Kommunalkredit Public Consulting (KPC). The program is carried out at federal levels. • Investment subsidies for the grid infrastructure are also available for the integration of renewable energy sources in order to reinforce the small-scale regional heat supply in rural areas as well as the expansion of district heating in urban centers (Heating and Cooling Network Expansion Act "WKLG").
	DHC production support schemes	• Investment subsidies for high-efficiency CHP plants are available through the Cogeneration Act (KWKGesetz). • Investment subsidies for solar thermal installations are available from the Climate and Energy Funds. This fund is also managed by the KPC.
Market	Total DHC sales to customers (2017)	• Heating : 21 015 GWh
	Main clients (in terms of sales, 2017)	• 43% residential, 41% tertiary, 15% industrial
	Main operators (in terms of turnover, 2017)	• Municipality owned companies: Wien Energie, Energie Graz, Salzburg AG, Linz AG, Stadtwerke Klagenfurt, Kelag Wärme, Energie AG, EVN,

As already mentioned in Annex 5, Graz DH network is not particularly representative of DHC in Austria as per today (major city, energy mix with a higher and higher share of RES and waste energy sources…), but it might turn into a **flagship project** and represent the future of DHC in the country.

6.10.2. Local context

Due to the basin location of Graz's urban area, the city faces **significant challenges in terms of air quality**, which constitutes an increasing concern for its population. These were met, among other things, on the basis of the **Styrian Regional Planning Act** and the designation of air quality remediation areas with the enactment of a "Municipal Energy Concept" in 2011. While heating is responsible for a significant share of the pollutants emission (see Figure 62), this concept describes the development possibilities for DH supply through a **"District Heating expansion plan"**.

This plan was prepared by the City Planning Office and the Environmental Office in close coordination with the relevant stakeholders, such as Energie Graz GmbH & Co KG (Graz DH network operator), Energie Steiermark AG (DH heat supplier) and the Energy Agency of Graz. It has no direct legal effect, but is a prerequisite for the ordinance of DH connection obligations.

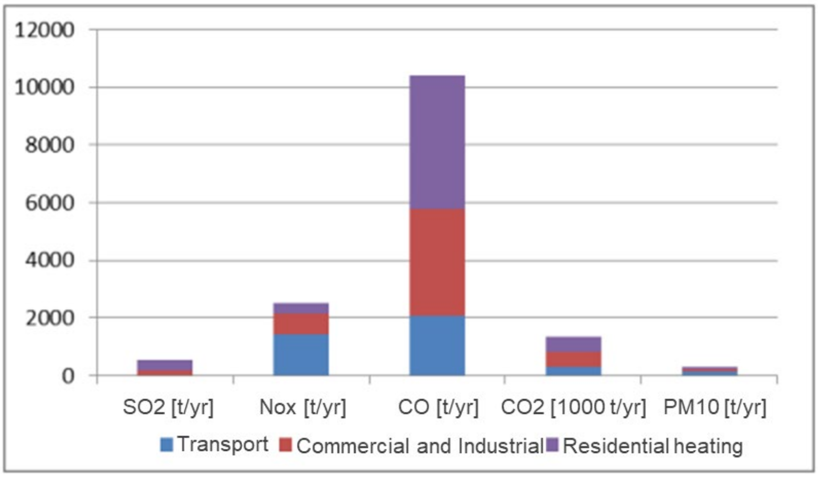


Figure 62: Sources of emissions of the different air pollutants in Graz (source: Stmk. LR 2008)

The **Urban Development Concept 4.0** represents the strategic planning instrument of the Provincial Capital of Graz for the next 15 years, which outlines the future development on the basis of ten principles (Stadt Graz Stadtplanung 2013). The goal of these principles is the realisation of a city with a high quality of life, which is why all urban development measures and projects must be in line with these principles in the future. Formally, Graz Urban Development Concept (STEK) is an ordinance under the Styrian Spatial Planning Act.

The increase of energy efficiency and the replacement of solid fuels for space heating and hot water production by piped energy sources is defined as the top priority. The support and promotion of heating conversion to DH, low-emission renewable energy sources, and natural gas are identified as essential objectives. As a result, **the City of Graz aims at increasing the share of DH supply in the total heating demand to 60% by 2030**.

Pursuant to the Styrian Spatial Planning Act, each municipality shall determine the obligation to connect to a DH system on its area if:

a) it is located in a priority area for air quality remediation,

b) it has adopted a municipal energy concept,

c) a binding commitment has been made by the DH supply company for the construction and expansion of the DH network.

As the City of Graz complies with these conditions, the STEK forms the basis for the preparation of **the zoning plan and subsequently the development plans**, which are prepared by the City Planning Office and adopted by the Municipal Council with a 2/3 majority.

Figure 63: Zoning Plan 3.0 - Restriction Zones for Space Heating (source: Stadt Graz Stadtplanungsamt 2003)

For the DH connection areas, priorities for further network expansion and the establishment of connections were set according to technical and economic criteria. On this basis, the city has decreed the basic connection obligation for the respective sub-areas. **In total, 54 districts are defined as DH zones in Graz.** The DH connection order applies to **all new buildings** in these areas with immediate effect, **and for the existing building stock the authority has to issue a notice within 10 years** with appropriate transition periods for the heating conversion to DH.

Table 20: Key urban indicators for the City of Graz

	City of Graz	
Statistics (2019)	Population	328 276
	Demographic trend (2011-2019)	+11.3 %/yr.
	Density	2,300 inhab./m²
	Housing (number of dwellings)	190 864
	Housing in multi-flats buildings	169 058 (89%)
	Heating degree days (with a reference temperature of 15°C)	3 670
Regulation	Urban regulation	The Styrian Spatial Planning federal law requires deep investigation of DH potential as well as implementation of heat supply solutions if feasible. Zoning is possible through DHC plans enacted by Municipalities.
	Building regulation (national)	The Austrian national building regulation directive "OIB-Guideline 6" aims for high energy efficiency standards in buildings and pushes toward efficient and RES-based supply, which can indirectly support the development of DHC systems

The total energy consumption for heating and domestic hot water in Graz is estimated at about 2,400 GWh per heating season today. **The share of district heating is about 50% of the total heat demand**. From 2001 to 2012, about 13 percentage points of additional residential units were supplied with district heating through new connections.

As depicted on Figure 64, DH is now the predominant solution for heating and Domestic Hot Water (DHW) in Graz. The alternative solutions breakdown has also changed over the past 20 years: if the electricity and gas shares remained relatively stable, **heating oil has been reduced significantly (and almost entirely replaced by DH).**

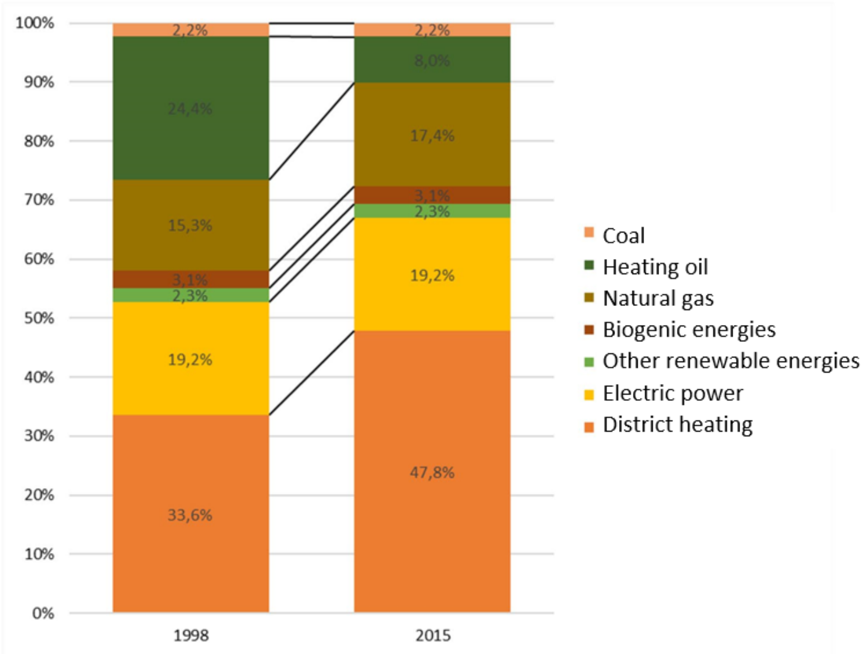


Figure 64: Evolution of the heating market in Graz (source: Grazer Energieagentur and Energie Graz)

6.10.3. Presentation of the DH system

Operated since 1963, the DH network of Graz has known many changes and **still evolves towards more ecological improvements**.

Figure 65: Key facts and figures of Greater Graz DH network (2018)

Key facts and figures	
DH market share	DH: 48% (2015)
RES share	15-25 %
CO_2 emissions (heating)	190 kg/MWh
Installed capacity	DH: 712 MW
Energy production	DH: 1 300 GWh/y
Km network (double-pipe)	DH: 412 km

The City of Graz counts on an **extensive grid that connects most of the inner city** (see Figure 66), as a strategy to eliminate the burners in the urban centre and thus improve the air quality. The city centre is also characterized by the **abundance of old buildings** from the "Gründerzeit" period (Gründerzeithäuser). These buildings are generally poorly insulated and present limitations for refurbishing, which adds a challenge for the modernization of the DH network (lowering the operating temperatures e.g.).

With the commissioning of **Mellach-Graz transport pipeline in 1986**, the DH supply area also began to expand outside the city area alongside this transport pipeline. The DH now supplies the city of Graz and its southern surroundings, gathered into the Greater Graz area.

Historically, the DH supply was mainly based on combined heat and power (CHP) plants. **Nowadays, the Greater Graz DH grid uses various energy sources mainly through decentralised heat feeders to produce up to 1 300 GWh/y with a 15 to 25% renewable share** (this figure keeps fluctuating since the DH network is experiencing major transition today, from historical gas boilers and CHP to diverse renewable and waste energies' facilities). Today, the energy mix is based on the following facilities:

- Natural gas boilers: total of 568 MW in the two different plants Mellach and Graz Fernwärmezentrale (FHG)

- A gas fired CHP plant (currently not supplying the DH)
- Waste heat recovery:
  - from the Sappi paper and pulp mill: 35 MW
  - from the Marienhütte steelwork and rolling mill factory: 15 MW
  - from chillers installed at Graz ice rink: 0.7 MW
  - from an incineration plant fired with biogenic wastes: 250 kW
- Thermo-solar plant: total installed capacity of 13 MW at several locations
- Biomass plant with a wood-chip boiler of 5 MW
- Storage facilities: 2000 m^3 at FHG and 2500 m^3 at Helios solar facility

Most of the supply to the grid is managed by Energie Steiemark AG, with the exception of the decentralised industrial waste heat and solar thermal heat production. While most of the heat supply is centralised (Mellach and Fernwärmezentrale plants), a non-negligeable number of decentralised production units, spread at various parts of the network, complexifies the network's operation.

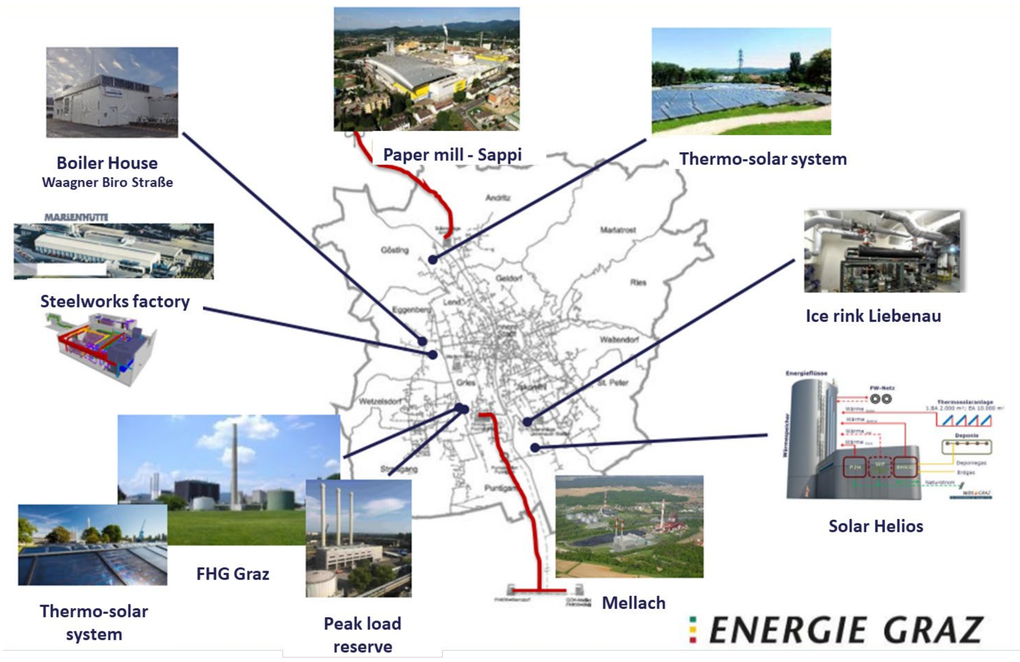


Figure 66: Illustration of the various energy sources supplying the Greater Graz DH (source: Energie Graz GmbH & Co KG)

6.10.4. Governance and business model

Governance and ownership

Initially developed by Grazer Stadtwerke AG in 1963, Graz DH network is now **owned and operated by Energie Graz GmbH & Co KG** (as the Stadtwerke disappeared when the energy market was liberalized in 2001). The company ownership is split between:

- Graz Municipality (51%)

- Energie Steiermark AG (49%), the company that supplies heat to the DH network (with the exception of the decentralised industrial waste heat and solar thermal heat production as stated above)

Like for the other DH networks in the major cities in Austria, **the Municipality is the main shareholder of the DH company and holds the majority of voting rights**. In addition to urban planning and financial support schemes also set by the Municipality (discussed hereafter), the City of Graz is therefore the leading actor of the development of the DH network on its area, with the overall objective of reaching a 60% heat market share for DH by 2030 as discussed in section 6.10.2.

In order to achieve this goal, the Municipality works in **close collaboration with the core stakeholders** for the DH projects:

- Energie Steiermark AG,
- Graz Energy Agency, which is deeply involved in the development of the network,
- the Province of Styria.

Figure 67: Graz roof scape (source: Graz Tourismus – Harry Schiffer)

Strategy and offer

Energie Graz GmbH & Co KG sells heat and domestic hot water to existing and new buildings in the Greater Graz area. The network has been expanded by 128 km in the last 10 years (2008 to 2018). This has made it possible to increase the number of homes supplied in the urban area of Graz to over 70,000, which means almost doubling in the last 10 years (see Figure 68).

In addition to network extension, further **densification** in the existing DH area will be continued and promoted, as this will further improve the efficiency of the DH network in addition to eliminating emissions from individual heating systems. In spring 2019, Energie Graz GmbH & Co KG, in cooperation with the City of Graz, launched a campaign for DH network densification in 5 priority areas with high useful energy demand, involving approximately 2,000 buildings (corresponding to 13,300 flats) that are not yet supplied with DH.

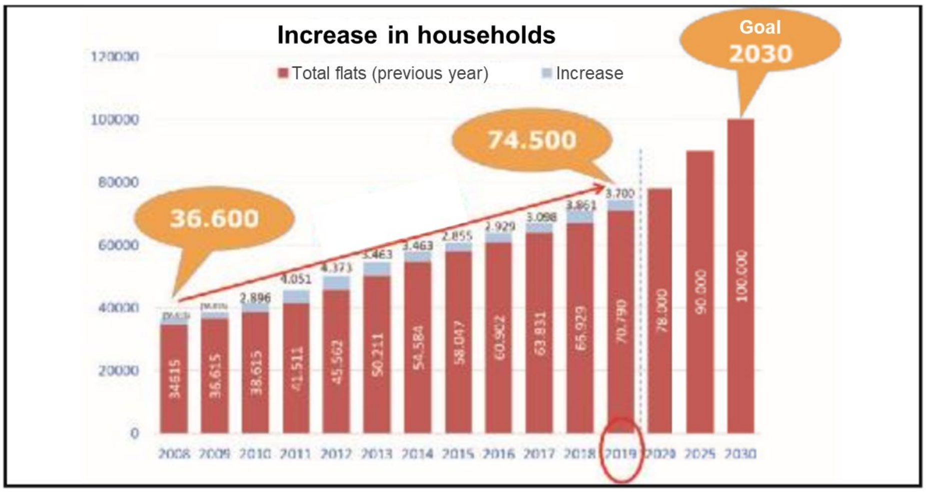


Figure 68: Increase in households supplied with DH in Graz (source: Energie Graz GmbH & Co KG)

According to the connection contract, customers undertake to exclusively purchase heat from Energie Graz, with the exception of **solar collectors** that can be installed on buildings for complementary supply. In practice, no disconnection has been observed.

Substations can be owned and operated by the DH operator or by the customers. The latter solution is commonly found for significant multi-flats buildings (30-1000 flats), especially when it results from converting oil boiler systems to DH.

According to the Heizkostenabrechnungsgesetz (the Austrian Heating Costs Billing Act, or HeizKG), a minimum of 55% and a maximum of 75% of the total energy costs shall be allocated according to **individual meters**, and the remainder (25-45%) by heated living space.

There is no bonus/malus scheme to optimize the return temperatures (which is especially important to allow an efficient integration of solar facilities in the DH network), but this topic is being discussed regularly within the working group of core stakeholders.

Financial model

The heating price is the same for all customers and is composed of:

- Two fix components:
    - an annual output price for the provision of thermal output, ranging in 2019 from 9,1 to 17,8 €/kW (including 20% VAT) according to the contracted capacity,
    - a metering price for the provision of the metering equipment required to measure the heat consumption, ranging in 2019 from 7,3 to 69,6 €/month (including 20% VAT) according to the nominal diameter of the connection.
- One variable component:
    - a commodity price for the thermal energy supplied, set in 2019 at 75 €/MWh (including 20% VAT).

These tariffs are regularly revised based on indexation formulas detailed in the contract. **As the energy mix of the network is evolving toward a fuel-independent heat**

generation (e.g., solar), a better price stability is being achieved. The orientation of heat generation towards a larger number of (decentralised) generation plants based on different energy sources also results in greater independence from individual energy sources (fuels) and individual generation plants (production shortage).

The price of DH in Graz is subject to the official price regulation. Pursuant to the Price Act, the authority may set economically justified prices for DH and the related ancillary services (operators shall cover their costs with limited profits). In Graz, DH prices were redefined for the last time with effect from 1st of August 2018 by means of a decision from the Office of the Styrian Provincial Government. The metering prices, which form an integral part of the tariff structure, are also regulated. The prices listed are **maximum permissible sales prices**. The DH purchase price of Energie Graz GmbH & Co KG from Energie Steiermark AG is also set on the same legal basis.

Substantial subsidies are provided by the Austrian Government, as well as by the Province of Styria and the City of Graz to support the switch to DH as well as for renewable energy sources:

- **For customers:**
  - Subsidy for heating conversion to DH by the City of Graz (subsidy according to social criteria)
  - Subsidies for DH connection costs from Energie Graz GmbH & Co KG and the province of Styria within the framework of housing energy renovation (choice between direct subsidy and annuity subsidy)
  - Subsidy for connection to local DH by the Federal Ministry of Climate and Innovation funds for environmental promotion in Austria (subsidy processing via the KPC)
- **For heat suppliers:**
  - Direct funding for thermal solar systems from the City of Graz and from the province of Styria
  - Direct subsidy for efficient biomass systems from the province of Styria
  - Direct subsidy for innovative technologies from the province of Styria
  - Subsidies for waste heat at local or federal levels

Subsidies are directed to customers and to some heat suppliers (fulfilling the criteria on energy types and innovation). However, since Graz DH network is still mostly supplied by gas boilers today, it has been difficult these last years for the operator to prove the positive environmental effects of the network and thus be eligible to such grants. Therefore, for both environmental and economic reasons, it is now very important to **achieve a rapid transition by integrating new projects with renewable energies** (like the solar project described below) **and waste energy sources** (see below as well).

6.10.5. Use of RES and waste heat

Since the creation of the DH network in Graz in 1963, **heat generation has been based mainly on CHP plants and in particular on the Mellach plant during 30 years**. However, due to the sharp drop in electricity prices in 2013, the maintaining of operation of CHP plants throughout Austria, and thus also the operation of the Mellach plant, were massively questionned. As a consequence, the heat supplied to the Greater Graz area from these plants was no longer secured.

In this critical situation, a working group was formed in 2013 under the leadership of the Graz Energy Agency. Its main goal was to organize and plan the **new strategy of the DH supply mix for 2020/30**. The main objectives were defined as follows:

- No deterioration in the primary energy factor of the DH, and thus the CO_2 balance
- No deterioration in specific emissions
- Consideration of the air quality issues in Graz
- No increase in costs compared to alternative heating solutions
- Maintaining security of supply

The process began in 2014 in an **extended working group** involving an intensive dialogue through 9 workshops with approximately 80 experts. A total of 38 proposals were submitted, discussed and reviewed. The best of them were implemented and the first new plants were able to start supplying heat to the DH network as early as 2016. Public communication and dialogue with experts continue to take place on a regular basis.

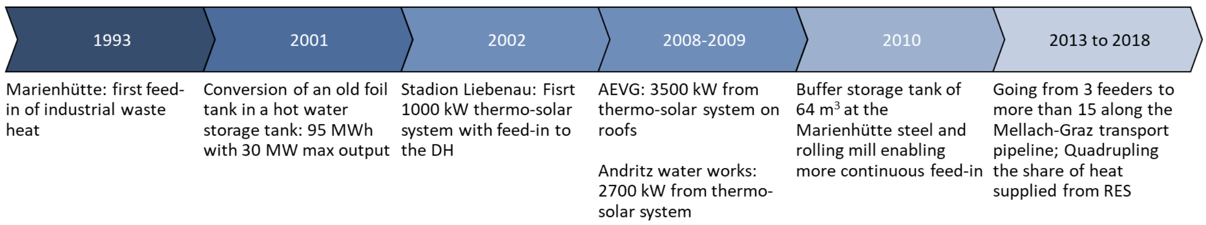
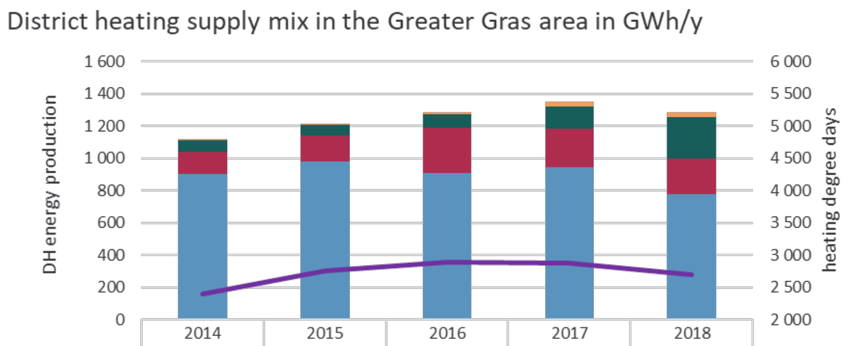


Figure 69: Historical milestones of the integration of RES

When designing the future DH system, the following principles are applied:

- **Maximum possible share of alternative energy** (RES and excess heat)
- **Additional energy efficiency improvement** in buildings, customer systems and for the overall DH system
- **Maintaining security of supply** by establishing gas-based heat generation capacities as a reserve for generation plants that are not continuously available (CHP, waste heat, solar, etc.) and for peak load in winter.

As a result, **new projects involving waste heat, solar and biomass have been implemented** and allowed to reduce the share of CHP. The figure below illustrates the evolution of the supply mix from 2014 to 2018 as well as the heating degree days.



	2014	2015	2016	2017	2018
Solar and Biomass	3	4	14	29	29
Waste heat	70	67	81	134	260
Gas Boilers	141	163	279	242	221
Highly efficient CHP	901	979	910	943	775
Heating degree days (20/12)	2 405	2 759	2 898	2 881	2 705

Figure 70: DH supply in Greater Graz area 2014-2018 (Graz Energy Agency)

As per today, **all CHP units have been shut down** (the last unit being shut down in 2020) and replaced by **gas boilers** to match the demand. This maintains the dependency of Graz DH on gas and its volatile prices. In the future, these gas boilers should count reduced operating hours and be used rather as back-up production.

To decrease the share of gas in the energy mix, numerous projects are already being implemented or in concrete preparation. These projects include major ones such as the 140 MW “Big Solar” project or the 35 MW excess heat recovery from Sappi paper industry (in operation). With this larger number of **decentralised heat production plants**, Graz DH network will also benefit from a **higher security of supply**.

The following figure shows the plants feeding-in the DH network of the Greater Graz area. A distinction is made between:

- Existing installations implemented before 2015 (pink marking)
- Measures already implemented between 2015 and mid-2019 (green marking)
- Measures currently in progress (blue marking)
- Measures in preparation or under in-depth examination (purple marking)

B1	Biomass plant – Wildon	6	Adaptation of the heating system waagner	14	Energy model Reininghaus
FHG	DH Central Graz plant	7	Energy model campus eggenberg	15	Energy efficiency measures in the DH (not represented on the map)
FHT	Thondorf power plant	8	Smart city – Energy model		
MH	Marienhütte waste heat	9	Expansion of the Central Graz solar plant	16	Waste heat recovery from Graz Karl-Franzens University
S1	Andrit water works solar plant	10	Heat surplus recovery from the Farina incineration plant	17	Waste heat recovery on wastewater treatment plant of the city of Graz (10 MW)
S2	Central Graz solar plant			18	Simulation of heat supply (not represented on the map)
1	Central graz district heating expansion (not on the map)	11	Wood chip biomass plant (5 MW)	19	Power to Heat system – Gössendorf
2	HELIOS: solar storage project			20	BigSolar Graz (140 MW)
3	Further waste heat recovery with heat	12	Renewal of boilers in Graz central	21	Additionnal potential on the Sappi paper mill
4	Waste heat recovery on the Sappi paper mill (35 MW)	13	New natural gas boiler back-up plants in Central Graz (198 MW)		
5	Waste heat recovery on Graz ice rink			22	Waste heat recovery on Linde Gas

Figure 71: District heating supply in operation and in preparation in the Greater Graz area (source: Status report 2019 – Energie Graz GmbH & Co KG)

Among all these initiatives, the **"Big Solar Graz" project** (number 20 in Figure 71) is remarkable as it would be the **world's largest thermo-solar collector for DH**. A detailed feasibility study has been carried out and highlighted the potential for a 450,000 m^2 collector field area (for a total of 250 MW) coupled with 1,800,000 m^3 seasonal storage and 96 MW absorption heat pump capacity. With this project, up to **25% of the heat demand** in Graz could be supplied by solar energy. In the long term, this project is supposed to be competitive with gas.

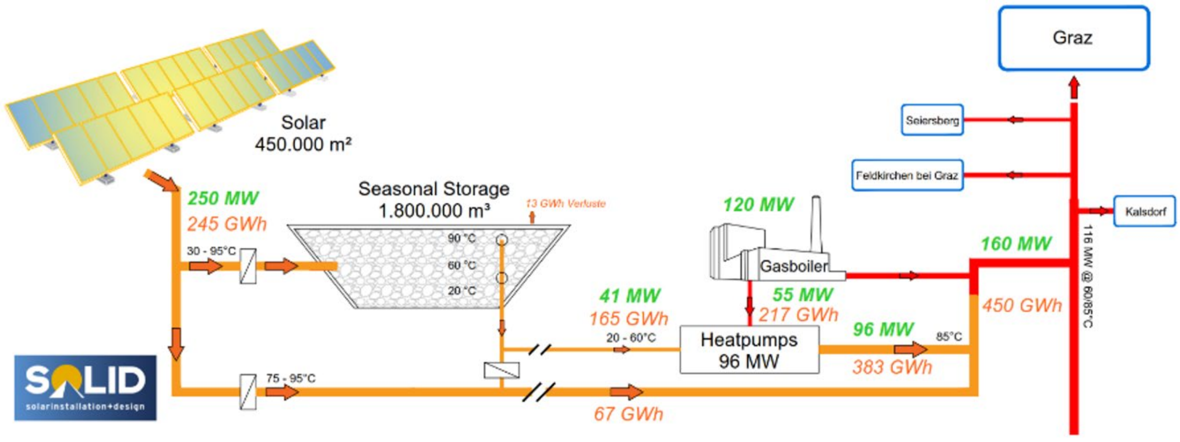


Figure 72: Concept of the "Big Solar project" for Graz DH network (source: Solid, 2020)

A recent study also highlights the **impact of reducing the return and supply temperatures of the DH network**. As shown in the graph below, a reduction of 10°C in both the supply and return temperature (green line) would increase the solar yield by 13% (total yield of the system including the planned storage facilities) and therefore increase the overall integration of solar in the DH production mix. It also underlines that reducing the temperature of the return flow (blue line) has more impact on the solar yield than reducing the supply temperature (red line).

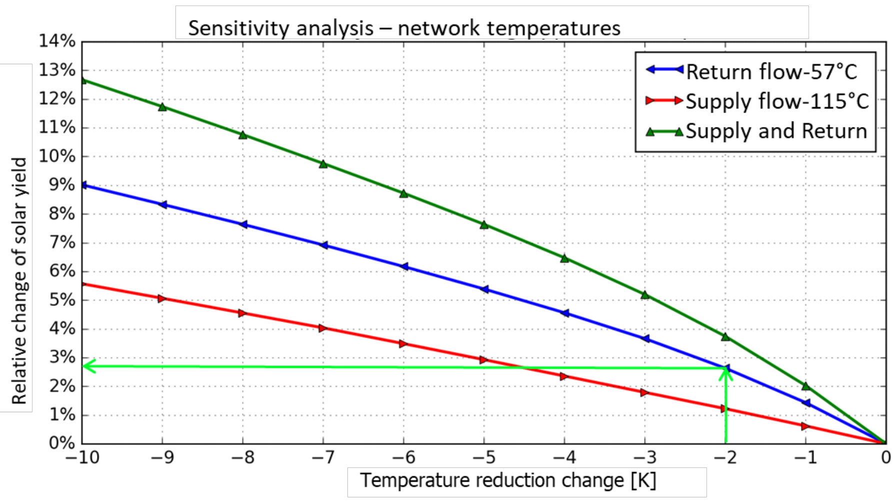


Figure 73: Analysis of the solar system yield in function of the network temperature (source: Solid)

6.10.6. Sector integration approaches and local value creation

The city of Graz encouraged the conversion from individual solutions (mostly oil heating) towards the connection to the DH grid. Between 2009 and 2011, approximately 41 MW of new connected load enabled the absolute reduction of emissions shown in the bar graph below and significant savings were achieved.

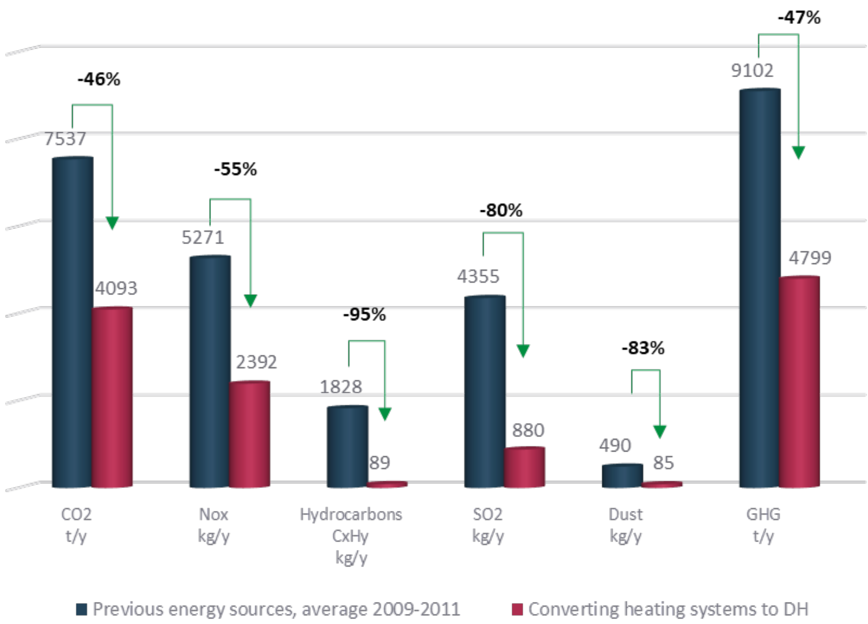


Figure 74: Reduction of the absolute emissions for the new connections to DH in Graz between 2009 and 2011 (source: Graz Energy Agency 2013)

Since then, the DH kept integrating more renewable and waste heat sources, finding fruitful **synergies with local industries and public infrastructures**. The partnership between Energie Graz GmbH & Co KG, the paper industry Sappi (providing excess heat) and Bioenergie (who facilitated the project and invested in the pipeline), is an excellent example of such cooperative projects. With a total amount of 23 million euros, 35 MW of heat were connected to the DH grid through 12 km of DH network in order to connect 40,000 households and save 20,000 tCO_2/yr.

Figure 75: Sappi project – Three partners for one shared vision

In accordance with the ambition to increase the RES share for the DH of the Greater Graz, the **"Graz Solar Roof Cadastre**" tool was created in cooperation with the City Surveyor's Office, the Environmental Office and professionals from the solar industry. It enables building developers, construction companies, solar developers and building authorities to assess whether solar installations are worthwhile for a specific property in Graz, for domestic hot water, heating or power generation.

The DH network also evolves in parallel with **building renovation**. For instance, during the renovation of two buildings of the Karl Franzens University of Graz, a combined cooling and heating system was built. Part of the low-temperature waste heat from the cooling circuit is used for the DH supply thanks to heat pumps.

Finally, Energie Graz GmbH & Co KG also works on customer systems in order to **improve energy efficiency measures on the customer side**. It is materialised by working on return temperatures, reducing power peaks, promoting energy services, consulting, conversion and renewal concepts, support, 24/7 troubleshooting and on-call service. Overall, consumers particularly appreciate the cleanliness, reliability and environmental friendliness of their DH system.

6.10.7. Prospects

The key features of the Graz DH development are the **openness and flexibility towards new approaches and solutions** and the regular examination of all available options. New technologies, improved economic environment or change of legal framework are taken into account in the core working team when making further decisions. The **medium-term goal is to achieve a 50% share of RES and waste heat** in the DH system within 5 to 10 years.

In the long term, the aim is to **phase out fossil supply** as much as possible in line with the Paris Agreement climate protection goals. Further measures include also efficiency improvement in the building stock and in heating systems, production plants based on biogenic fuels, solar energy, and heat pumps that enable the use of heat from low temperature sources, such as geothermal energy.

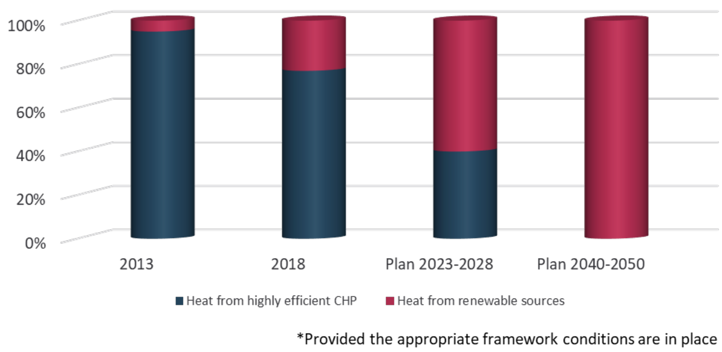


Figure 76: Planning DH supply mix of the Greater Graz (Energie Graz GmbH & Co KG)

In new urban development areas, decentralised low-temperature heat supply systems based on the energy models already developed and tested by Energies Graz GmbH & Co KG will be preferably implemented.

6.10.8. Conclusion

Graz DH network is a good example of **how DH networks develop in urban areas replacing individual fossil fuels-based solutions** and how these networks can **evolve to integrate multiple renewable and waste energy sources**, including solar thermal energy in this case.

The key success factors enabling the integration of RES and waste heat can be summarised as follows:

i. **A strong push for transition from both public and private stakeholders**. The Municipality, through its public operator Energie Graz, plays a key central role here, and is able to coordinate with other public actors (for the design of the DH network or for the financial support schemes e.g.) as well as private actors involved in the development of the DH network and its heat supply. The DH network is used as a municipal tool to improve air quality and decarbonise the city.

ii. **The openness to new ideas.** The working group led by the Municipality and involving the core stakeholders (Energie Steiermark, Graz Energy Agency, the Province of Styria) as well as relevant experts is an excellent tool to foster communication, common understanding and new initiatives.

iii. **The long-term planning to organize a realistic and efficient phasing-out of fossil supply**. With the decision to shut down the CHP plants taken in 2013, the Municipality has endeavoured to develop a long-term thinking of the evolution of the DH network, aiming at reducing its carbon footprint and increasing the air quality, ensuring security of supply, and remaining competitive against alternative heating solutions. While efforts still need to be made to increase the renewable and waste energies share, Graz DH already contributed very successfully to replace coal-heated flats and to reduce the emissions of dust, NOx and SO_2.

iv. **The integration of all possible local opportunities**. In order to achieve the objectives mentioned above, Energie Graz has managed to address all the possible solutions and to mobilize all the required experts in order to be able to make the appropriate arbitration. Thus, a remarkable variety of new projects is being operated or under preparation to ensure the heat supply for the future of Graz DH network: solar, biomass, excess heat from different sources (industry, waste water treatment plant…), power to heat…

v. **The availability of investment subsidies**. Several financial support schemes are available at national, federal and local levels to foster the development of efficient production and distribution of RES heating and cooling.

6.10.9. References

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- Status of current projects of Energie Graz to the District heat application – Ing. Wolfgang Knaus – 27/06/2017
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6.11. Case study of Jelgava (LV): modernization and decarbonization of a major DH system

Foreword

Fortum[49] signed on March 2021 an agreement to sell its DH business in the Baltics including the DHC system in Jelgava to Partners Group[50], a leading global private markets firm, acting on behalf of its clients. At the time of writing this report, the deal was under closing process, expected to be completed in the second quarter of 2021. As the owner of the Jelgava assets until then, Fortum has provided the information for this study. The future strategy and actions will be managed by the new owners.

6.11.1. National context

With the 2030 objective to reach 50% RES share in its final energy consumption (and more particularly 63% RES share in DH), Latvia is ahead of the EU-wide goals (40% RES share in final energy consumption). However, the DH market is globally slowing down in Latvia because of the population's decline and the low efficiency of DH systems conducting to a high heat price. For the moment, the few support schemes in place are not sufficient to reverse this trend.

Table 21: Key facts for DHC in Latvia

DHC in Latvia - Key facts		
Regulation	Regulators / Supervision authorities	• DH systems in Latvia (exceeding 5000 MWh/year heat sales) are highly regulated for production, transmission/distribution and sales • Third-Party Access (TPA) is promoted: DH operators are obliged to purchase heat from any third-party suppliers if the offered price is lower than the DH operators' price • The Ministry of Economics is the responsible institution for energy sector • The Public Utilities Commission (PUC) is a multi-sector regulator overseeing district heating. It is responsible for licensing/registration, tariffs, protecting consumer interests, promoting competition, resolving disputes and controlling quality
	Role of municipalities	• Owner of most of the DHC companies (owning and managing DHC networks) • Responsible for heat supply in their administrative territory in compliance with energy efficiency and competition promotion
	Ownership (in terms of sales, 2018)	• DH networks are owned and managed by individual heat supply companies. Majority of them are municipalities owned (>90%)
Support schemes	DHC support schemes	• Investment grants are available under European Union Structural Funds and Cohesion Fund for the 2014-2020 planning period under specific target 4.3.1. "Promote energy efficiency and the use of local RES in district heating" • RED article 24 to promote the integration of RES and waste heat in DHC has not been implemented yet at the national level (currently under discussion)
	CHP support schemes	• Subsidies for electricity produced in high efficiency CHP is available under current scheme as Feed-in tariff or Capacity payments (currently under discussion)
Market	Total DH sales to customers (2018)	• Heating: 6 865 GWh (36% of the total heat market)
	Main clients (in terms of final energy consumption, 2018)	• 63% residential, 22% tertiary, 15% industrial
	Operators	• Most of the DH operators are local and operate only one network

[49] https://www.fortum.com/
[50] https://www.partnersgroup.com/en/

The case study of Jelgava DH is representative of the national context since it is supplied partly by a **biomass CHP plant**. Indeed, all larger DH systems are in majority supplied by CHP plants which are more and more switching from natural gas to biomass. This case is of particular interest since it is the largest bio-fuelled CHP plant in Latvia.

6.11.2. Local context

Jelgava is a city located in central Latvia, 45 km south-east from Riga. It covers an area of 60 km² and has a population of around **62,800 inhabitants**. It is the largest town in the Zemgale region and its heat market is the third biggest in Latvia.

Jelgava has a well-developed district heating system, which supplies about 85% of the city's total heat consumption. Parts of the network date back to the 1950s.

Figure 77: Aerial view of Jelgava (source: www-storyblocks-com.aii.idm.oclc.org/)

As Jelgava was completely destroyed during the Second World War, the renovation of the buildings was concentrated in the central part, and lasted until the late 1980s. **Most of the residential buildings have been built in the time period from 1960 to 1989 (79%).** Unfortunately, with limited resources allocated to the housing policy, residential construction in several places of the city resulted in unfinished residential blocks or groups of buildings, which **fragmented the building structure of the city, causing large energy losses.**

The residential areas built during the Soviet times are very large, impersonal and of utilitarian type, and **the technology and construction quality is very low**. These buildings are the key concern for the city today, as it is necessary to improve the energy efficiency of the buildings and to reduce their energy consumption. The task is particularly difficult due to the fragmented property ownership of apartment buildings.

In its **Sustainable Energy Action Plan for the years 2010-2020** prepared by the Zemgale Regional Energy Agency (ZREA) in accordance with the Covenant of Mayors, the City of Jelgava has targeted to reduce its CO_2 emissions by 20%, to increase energy efficiency by 20% and to raise the share of renewable resources in energy production by 20%.

More specifically, as the DH owner, the Municipality elaborates the development plans for its DH network. However, municipalities in Latvia cannot limit consumers' choices regarding the type of heating solutions, no matter in what part of the city they are located (i.e., **zoning is not possible** in Latvia).

Table 22: Key urban indicators for Jelgava city

Jelgava City		
Statistics	Population (2020)	56,062
	Demographic trend (2017-2020)	-3 %/yr.
	Density (2020)	928 inhab./m²
	Housing (number of dwellings)	-
	Housing in multi-flats buildings	- (%)
	Heating degree days (with a reference temperature of 15°C)	4 430
Regulation	Urban regulation	No zoning
	Building regulation (national)	The Law on the Energy Performance of Buildings obliges owners of new or renovated buildings to consider using RES heating and cooling systems

In Latvia, DH is competing with individual, building-specific gas boilers, which are only marginally impacted by CO_2 emissions excise taxes. This still makes, for the time being, those gas boilers competitive.

On the other hand, DH suppliers have to offer one-component prices (energy-only component) on equal basis for all customer segments, which prevents them from making tailored offers that would integrate the different technical constraints (contracted capacity, distance to the network…) and thus limits the connection of new customers in many cases.

6.11.3. Presentation of the DH system

Jelgava DH supplies heat and Domestic Hot Water (DHW) to **365 residential buildings** (16,000 households) and **172 tertiary and industrial customers** (about 22% of the total heat sales).

The heat is produced from six different units:

- One biomass CHP plant (45MWth and 23 MWe), which can supply up to 85% of the DH demand
- One gas CHP plant (5 MWth and 4 MWe)
- Four gas-fired boilers (109 MWth)

Table 23: Key facts and figures of Jelgava DH network (2020)

Key facts and figures	
DH market share	ca. 85%
RES share	80%
CO_2 emissions (heating)	ca. 25 gCO_2/KWh
Installed capacity	Heat: 159 MW (45 biomass) Electricity: 27 MW (23 biomass)
Energy production	Heat: 230 GWh/y Electricity: 1110 GWh/y
Heat losses	16%
Km network (double-pipe)	DH: 75 km

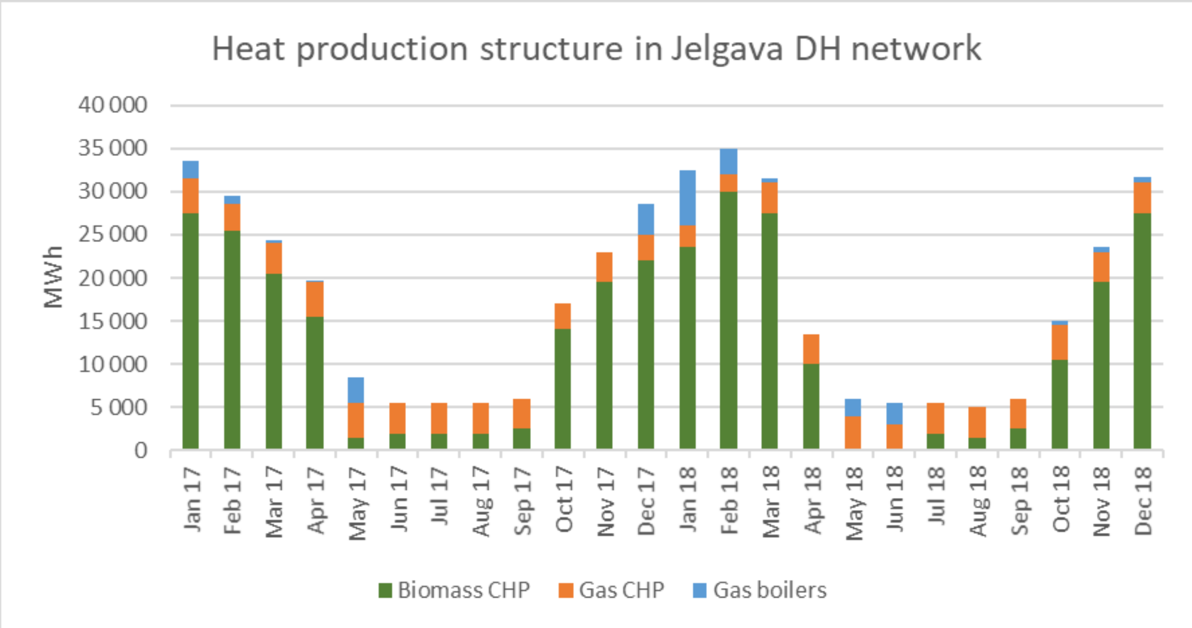


Figure 78: Monthly heat production and energy mix for Jelgava DH network (source: Fortum)

Jelgava DH used to be 100% natural gas-based using boiler houses. **Since 2008, the current operator invested around 95 M€** for the following works:

- **Major network renovation and interconnection of two district heating systems** under the Lielupe river (1408 m pipe, including 380 m under the river) in order to maximise the use of the biomass plant;
- **Replacement of all heat production units;**
- **Construction of the bio-cogeneration plant based on biomass.**

This large biomass plant using local and renewable biomass provides customers with safe, efficient and environmentally friendly DH at a competitive price. **It has enabled to drop the CO_2 emissions by 70% compared to 2010.**

Figure 79: Map of the network and photo of the biomass CHP plant (source: Fortum)

6.11.4. Governance and business model

Governance and ownership

In the Soviet period, heat tariffs were extremely low. When fuel inputs (mostly gas and oil, but also to a limited degree coal) started to be sold at world market prices in the early 1990s, the Latvian Government transferred the responsibility for the DH sector to municipalities. Thus, **Jelgava District Heating Company (JDHC) was established in 1992 as a municipal enterprise**.

However, like the other municipalities, the City of Jelgava faced difficulties in balancing:

- its role as owner of the DH companies, which required to raise tariffs to recover rising costs (to buy fuels at market prices, but also to finance the rehabilitation of the DH network which was in extremely poor technical conditions worsened by rampant corrosion caused by high ground water levels and floods of the Lielupe River),
- its role as supporter of the interests of consumers, whose incomes did not rise at the same pace.

A first major rehabilitation occurred in the late 1990s, supported by different sources of national and international public funding (including the World Bank). This rehabilitation allowed to extend the life expectancy of the DH system from 5 to 30 years. However, **JDHC experienced additional financial difficulties** in the early 2000s caused by the heritage of another DH network in poor condition on the right bank of the Lielupe River, the decline in the local economy, the overly optimistic heat demand forecast, and the energy regulation that let the gas be more competitive than DH and thus drove a 23% loss of customers (shifting to individual gas boilers), including municipal and state-owned buildings.

As a result, in 2008, the City of Jelgava set the **concession of Jelgava DH network for 30 years**. The concession was assigned to the Finnish energy corporation **Fortum, which holds 100% of the project company**.

The project company is split into two legal entities: **Fortum Latvia** is in charge of the heat and electricity production, while **Fortum Jelgava** manages the network and provides customer service.

Strategy and offer

Jelgava DH provides **heat and DHW** to its customers. About 78% of the heat sales are directed to the residential sector (mostly multi-flat buildings), while tertiary buildings and industrials represent about 12% and 10% respectively. Such proportions of residential customers in the customer portfolio make Jelgava DH rather sensitive and attract local political interests regarding DH price-setting and services, bearing in mind that in the past all DH in Latvia has been under municipal steering.

Fortum Jelgava operates the network as well as the substations at customers' buildings (if requested by the customer). The operator also provides on his website interesting materials to its customers in order to support them to commit to an increased efficiency of the DH system and thus a reduced energy bill (energy saving tips, temperature regime settings…).

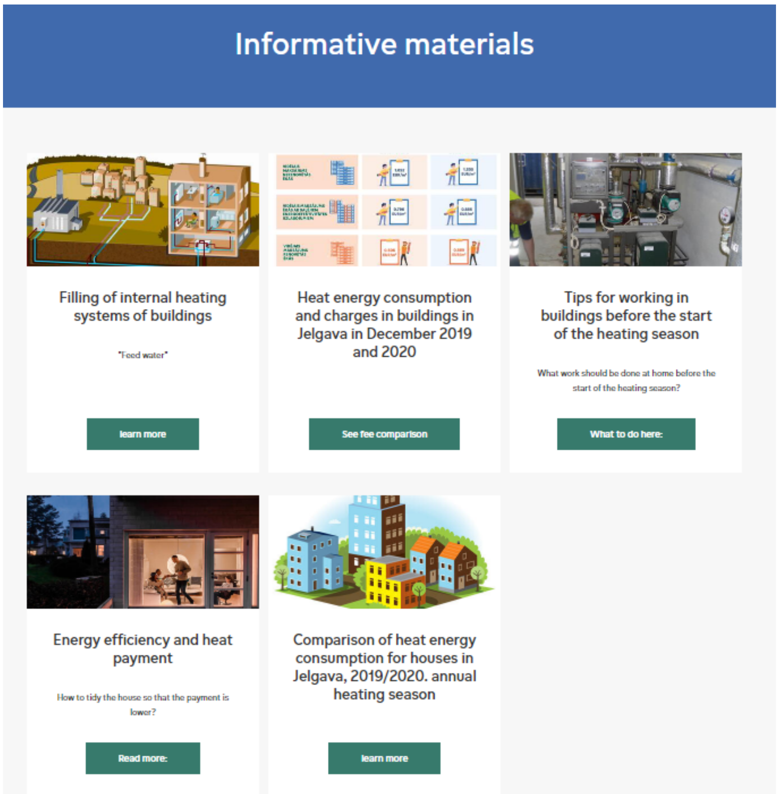


Figure 80: Information available to customers to support energy efficiency (source: Fortum Jelgava website)

As discussed already, zoning is not authorized in Latvia so customers have a free choice of their heating method even when they are located in the vicinity of an existing DH network.

While there are no particular subsidies to support connection to DHC grids, **connection fees are ex-ante regulated** by the Public Utilities Commission (PUC).

Billing is carried out every month on the basis of heat meter readings. **Heat cost allocation rules** are described in the Cabinet of Ministers Regulations No. 524 (15/9/2015). This law has eleven annexes, describing several different types of calculation methodologies, according to the presence in the buildings of heat meters and/or heat cost allocators.

The apartment owners can decide and agree in their assembly which calculation rules to apply (e.g., heating costs allocated by flat area or by metered consumption or a combination of both). Correction factors, taking into account intrinsic different heat losses of flats, may also be used. These factors are calculated for each building by an independent expert on energy performance of buildings.

Financial model

In Latvia, the final heat price for consumers is set by the Public Utilities Commission (PUC) based on the application made by the DH company. **Prices are ex-ante regulated by a cost-plus principle over a 1-year period**, and heat operators are **not allowed to offer differentiated prices** to different customers. Prices typically include only the energy component (though it is possible to apply for 2-component price).

Value Added Tax (12%) is applied to heat energy for households regardless of the type of heat production and fuels used.

Jelgava's DH operator invoices its customers through a **single component tariff expressed in €/MWh** that includes heating and DHW. The current tariff approved by the PUC is set at 52.5 €/MWh excluding VAT.

Compared to the previous years, the tariff has been reduced thanks to a drop in fuels costs (both biomass and gas). **The significant replacement of gas by biomass in the total energy mix of the DH network has allowed to stabilize and globally reduce the tariff for the customers over the past years.** As depicted in the figure below, gas faced a 300% increase in price between 2005 and 2012 (i.e., just before the commissioning of the bio-CHP), while biomass increased by 85% only over the same period.

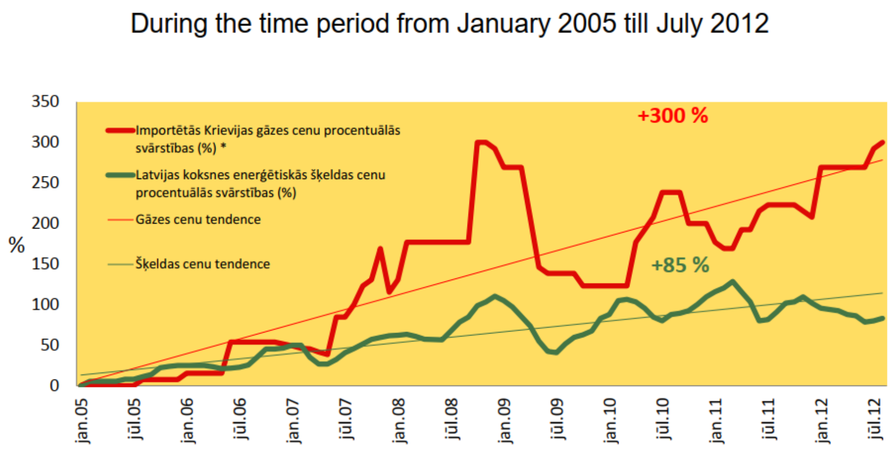


Figure 81: Fuels price increase (in %) over the 2005-2012 period for gas (in red) and biomass (in green) (source: Fortum)

On top of the 20 MEUR funding (mostly by the World Bank) for the late 1990s rehabilitation, **the project benefited from 6 MEUR from EU funds to support the implementation of the biomass CHP plant** (out of 70 MEUR investment).

6.11.5. Use of RES heat

With the commissioning of the biomass CHP plant in 2013, Jelgava DH network has entered a completely new era, cutting the CO_2 emissions from 180 down to 25 gCO_2/kWh (reduction of about 35,000 tons of CO_2 per year), and decreasing

the heat price from 75.5 to 58.6 €/MWh (and even lower today)**.** Before that, Fortum had already reduced the emissions from 220 to 180 gCO_2/kWh thanks to the replacement of all existing heat production units.

The installed capacity of the biomass CHP is 45MWth and 23 MWe. The plant is able to generate up to 230 GWh of heat and 110 GWh of electricity per year, with an efficiency of 88%. The 170,000 tonnes/year biomass (including but not limited to wood chips, sawdust, bark, wood residues, grain by-products, straw, other plant products, agricultural and forestry residues, peat) is sourced from 7 different local suppliers, and require a total of 25 to 30 trucks per day in winter.

Today, **the plant supplies up to 85% of the DH demand** and is almost fully utilized during the heating season. As presented in the figure below, the 5 MWth gas CHP is still used as baseload, while the gas boilers are now used for peak and back-up only. Waste heat is not relevant for Jelgava DH system today as very few producers have waste heat potential and volumes are too small to be connected to the network.

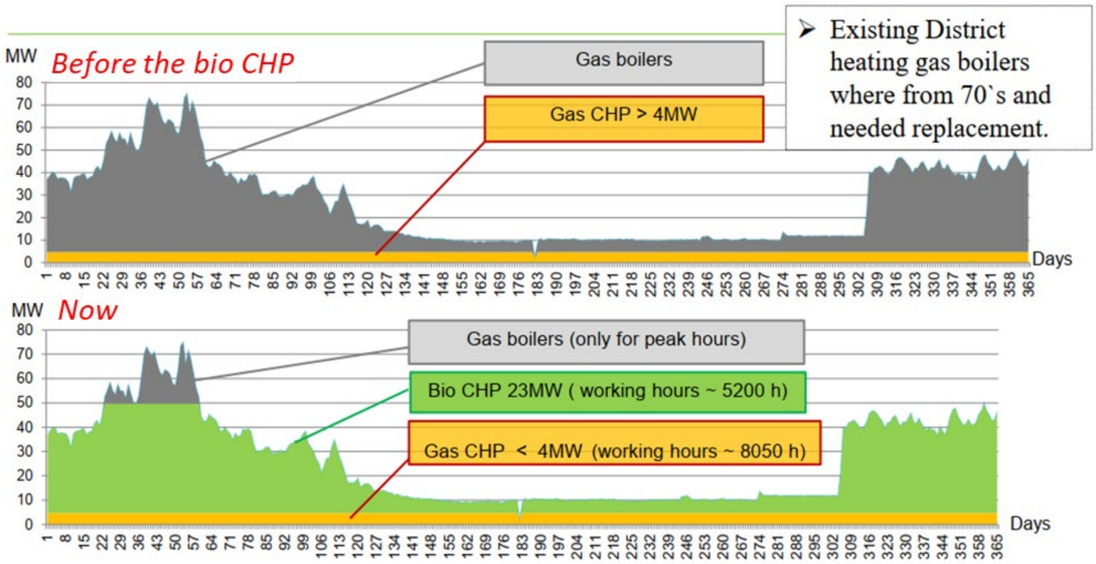


Figure 82: Production profile and energy mix before and after the commissioning of the biomass CHP plant (source: Fortum)

More specifically, the biomass CHP plant uses a Boiling Bed Combustion technology (see Figure 83). This technology is widespread in Europe and especially in Scandinavia. The main advantage of the **fluidised bed** process is the energy stored in the fluidised bed sand, which allows **efficient combustion and better automation and control** of the combustion process, hence higher efficiency and combustion stability, as well as the **possibility to co-fire lower quality biomass fuels** with low calorific value, high moisture content, different chemical composition and fine fraction.

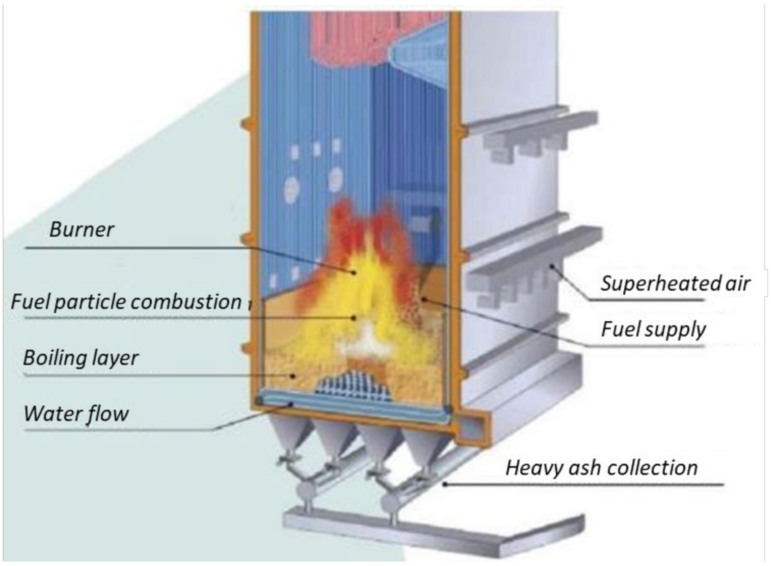


Figure 83: Schematic diagram of fluidised bed technology (source: Fortum)

With plans to further reduce the use of imported fossil fuel as well as to continue connecting new customers to the DH in the long term, it is planned to increase the average annual load of the biomass CHP plant from 60% to 82%. Fortum Latvia, using the long-standing experience of the Fortum group, including in the field of circular economy and waste incineration, **plans to diversify the existing types of fuel (biomass) and to integrate Refuse Derived Fuel (RDF)**.

In the design phase, it is planned that the total amount of RDF to be co-fired with biomass will be up to 30,000 tonnes/year. As the fluidised bed technology is recognised as the most appropriate technology for co-incineration of RDF (compared to moving bed incinerators), it would not have to be changed.

6.11.6. Sector integration approaches and local value creation

In Jelgava DH system, the main vector for sector integration is the **biomass CHP plant (45MWth and 23 MWe)**. However, no balancing service for the electrical grid has been contracted yet.

Another source of sector integration that has started to be studied recently is the **production of CHP-integrated pyrolysis oil**: upstream of the fluidized bed boiler, the fine-milled dried wood chips enter a pyrolysis reactor (500°C) and is distilled almost instantaneously into pyrolysis gas (condensed into bio-oil at a further stage) and char (directed to fluidized bed boiler). This could increase the overall energy efficiency of the plant, increase fuel flexibility (by handling an even wider variety of biomass fuels) and generate additional revenue potentials (by selling this bio-oil to biorefineries and industries).

In addition, it is estimated that the bio-CHP implementation has created **around 300 indirect jobs** in the fuel supply chain.

6.11.7. Prospects

The renovation process to improve energy efficiency in buildings has been ongoing since 2009, with support of national programmes (some being co-financed by EU funds). **In Jelgava, 21 multi-flat buildings have been renovated** so far and 4 more are in the pipeline for the coming years. After the refurbishment, **energy savings of 50-60%** are usually achieved. To compensate this reduction in energy consumption per building, the City of Jelgava has set **the extension of its DH network as one of the main priorities**.

The **Jelgava Development Strategy** sets out the city's vision for the development of the heat networks and focusses on ensuring high energy efficiency, safety, and reduced carbon emissions. The strategy includes the introduction of modern technologies for heat production, the optimisation of the district heating system in districts on the right bank of the Lielupe River, and the planned renovation of previous distribution network.

In addition, the introduction of a **centralised cooling system** is being evaluated. Monitoring the development of new activities (e.g., new shopping centres, office buildings or educational institutions) will help estimating the potential for a DC solution in the city.

6.11.8. Conclusion

Jelgava DH network is a flagship example of the **modernization and decarbonization of a major DH system in a highly-regulated country.** The key success factors identified in the case study are summarised below:

i. **The historical commitment of the Municipality to the DH system**. Even though the DH network is now operated as a concession, it has been developed for more than 60 years and is at the hearth of the City's energy strategy, supplying about 85% of the city's total heat consumption. The intensive and good co-operation between the municipality and the DH operator has been one key success element which cannot be undervalued.

ii. **The operational experience and financial capacity of the private operator**. The operator managed to finance the 95 M€ required for the modernization of the network, and implemented successfully the different technical solutions (replacement of all heat production units, commissioning of a 45 MWth fluidised bed biomass CHP plant, network renovation, interconnection of the network under the Lielupe river…) while ensuring a proper service continuity.

iii. **The significant EU/national support schemes to foster the development of biomass CHP**, which enabled the decarbonization of Jelgava DH network, dropping the CO_2 emissions by 70% in 10 years (saving about 35,000 tons of CO_2 per year).

iv. **Competitive and stable prices thanks to the integration of local and renewable energy.** The significant replacement of fossil fuels by biomass has allowed to stabilize and globally reduce the tariff for the customers over the past years (from 75.5 to 58.6 €/MWh), which is important in the current context of a gas price still relatively low.

v. **Culture of innovation.** The innovative approach and multi-fields (including circular economy) experience of the operator are key to ensure continuous improvement of the DH system: new solutions being investigated include the diversification of existing types of biomass, the integration of Refuse Derived Fuel (RDF), and the implementation of pyrolysis oil.

6.11.9. References

- Sustainable Energy Action Plan of Jelgava City for the years 2010 – 2020, Jelgava City Council, 2010
- Presentation "Fortum for a cleaner Word", Fortum Latvia, 2019
- Biomass CHP – a sustainable solution for Jelgava heat supply, Fortum Latvia, 2013
- Fuel diversification in an existing biomass CHP plant in Jelgava – Environmental impact assessment report, Fortum, 2020
- Sustainable development of biomass CHP in Latvia, T. Prodanuks et al., 2015

6.12. Case study of Plock (PL): complete decarbonization through the use of industrial waste heat

6.12.1. National context

There are roughly over 400 DH systems in Poland serving some 16,5 million urban citizens (**42 % of all population**). The average CO_2 emissions have been relatively stable during the last 10 years, varying between 360-370 gCO_2/kWh: **fossil fuels cover over 90% of DH production** while renewables (including the biodegradable share of waste) cover only 4%.

Table 24: Key facts for DHC in Poland

DHC in Poland - Key facts		
Regulation	Regulator / Supervision authority	• Energy Regulatory Office (ERO), which issues the concessions and regulates the activity (tariffs, grid access, metering…) • National Competition Authority
Regulation	Role of municipalities	• Energy and urban planning at local level • Municipalities are key customers of DHC as public buildings owners • Municipalities are also most usual owners and operators of smaller DH networks
Regulation	Ownership (in terms of sales, 2018)	• Largest DH systems are owned by private companies (about 30% of the market) • Municipalities and State owned utilities own and operate DH systems in small and medium cities
Support schemes	National energy and climate strategy	• The National Recovery and Resilience Plan is a comprehensive document presenting goals related to the reconstruction and building of socio-economic resilience in Poland after the crisis caused by the COVID-19 pandemic • Environmental Protection Act • Act on Thermal Rehabilitation • Renewable Energy Sources Act and Priority Program RES "Stork" (for distributed renewable energy)
Support schemes	DHC support schemes	• The National Fund for Environmental Protection and Water Management provides subsidies and low-interest loans for DH companies, municipal government and other companies • It also provides loans to support projects increasing the efficiency of H&C systems in existing industries, including construction or modernization of generating units as well as connection to DH network • The Clean Air Program also sets stricter emission limitations for small (individual) boilers, limits the use of solid (coal) fuels in households, and supports the connection of multi-family buildings to a collective hot water installation • White certificate scheme (energy savings)
Support schemes	RES support schemes	• The National Fund for Environmental Protection and Water Management grants low interests loans to support the purchase and installation of RES installations (all RES are eligible). The duration of the scheme is 2015-2023, with maximum loan of 9.31 M€, limited to 85% of eligible costs. • New scheme for boosting RES under consideration (REDII imposition)
Support schemes	CHP support schemes	• Premium for the electricity produced by CHP based on an auction system • Guarantee of origin through red certificates (high-efficiency CHP, not valid any more), green certificates (bio-CHP) and yellow certificates (gas-CHP)
Market	Total DH sales to customers (2018)	• Heating: about 60 TWh/yr (serving 42% of the population)
Market	Main clients (in terms of sales, 2018)	• 72% residential, 24% tertiary, 4% industrial
Market	Main operators (in terms of turnover, 2017)	• Private operators from national (Termika, PGE, Tauron and ECO) and international (Dalkia, CEZ, Fortum) companies

Currently industrial and tertiary waste heat is covering about 5 % of total DH energy mix and this share has been increasing gradually from about 1 % in 2011. Together with waste incineration, this waste heat is thus steadily increasing and replacing fossil fuels in Poland. Therefore, **the case study of Plock DH network, fuelled by industrial waste heat, constitutes an inspiring example for the decarbonization of DHC and is representative of the mid-term evolution of DHC in Poland.**

6.12.2. Local context

Plock is the historic capital of Mazowsze, located in the north-western part of Mazowieckie Province, at the distance of about 110 km from the capital Warsaw. After the substantial losses in terms of population resulting from the Second World War, **Plock became a significant industrial centre of the region of Mazowsze** (petrochemical plant, harvesting machines factory, textile factory… shaped mainly by large, state-owned industrial companies) and passed from 34,000 inhabitants in the early 1960s to **about 120,000** in the late 1980s. The population has been stable since the last 30 years and Plock is a medium-size city in Poland now. The main industry today is still the oil refining plant of PKN Orlen (a state-owned oil refinery that is listed in Warsaw Stock Exchange).

Figure 84: Aerial view of Plock, with the industrial area in the background (source: https://www.worldisbeautiful.eu/)

On November 29, 2016, by Resolution No. 438 / XXV / 2016, the Płock City Council adopted the **Environmental Protection Program for the City of Płock for 2016-2022**. The aim of the Program is to present guidelines for rational activities for the following years and to improve the condition of the natural environment, or to maintain a good level where it was achieved as a result of the assumptions of the previous program.

The investment, organizational and information solutions contained therein will contribute to the proper management of natural resources in line with the principles of sustainable development. This document fulfils the obligation of the City of Płock to update strategic documents, which allows the authorities to monitor the state of the environment on an ongoing basis and plan activities aimed at environmental protection on this basis.

Table 25: Key urban indicators for Plock city

Plock City		
Statistics (2017)	Population	119 425
	Demographic trend (2012-2017)	-0,6 %/yr.
	Density	1 337 inhab./m²
	Housing (number of dwellings)	*Not available*
	Housing in multi-flats buildings	*Not available*
	Heating degree days (with a reference temperature of 15°C)	3 728
Regulation	Urban regulation	Zoning: not possible in Poland
	Building regulation (national)	Thermal rehabilitation grants: supports building renovations which reduce energy demand and losses, lower heat costs, or replace existing heat generation units with renewable or high-efficiency CHP plants

In Poland, **DH represents ca. 42% market share of the residential buildings, while direct coal use represents ca. 39%, gas use ca. 10% and direct use of firewood is approximately 7%.** Poland is therefore facing significant air quality issues and has set up the Clean Air Program to reduce dust emissions and other pollutants from single-family houses.

However, **with still a low carbon price tax on individual gas and coal-based heating systems, DH is still experiencing difficulties to be competitive against these alternative solutions**. The possibility of a transitional mandatory share of low carbon heat sources for new buildings and deep renovations is being considered now. If approved, this would foster the development of DH in the country.

As presented in Table 25, **mandatory connection to DH networks (zoning policy) is not possible in Poland today**.

6.12.3. Presentation of the DH system

Plock DH system is an **old network** built before 1960 which used to be entirely supplied by fossil fuels. It was recently upgraded including a **complete decarbonization through the use of industrial waste heat, which was found to be the most competitive solution**.

Therefore **almost 100 % of the current DH demand is supplied by industrial waste heat from the local oil refinery** operated by PKN Orlen, which uses a CHP mainly fuelled by natural gas for its own industrial processes.

This network **supplies the majority of the local heat demand (about 65 to 75%)** and it is expected that this market share remains stable since buildings refurbishments (which will reduce the demand) should be compensated by the connection of additional buildings.

Table 26: Key facts and figures of Plock DH network (2020)

Key facts and figures	
DH market share	~ 65% - 75%
RES share	~ 100% (waste heat from industrial process)
CO_2 emissions (heating)	~ 0 kg CO2 / MWh
Installed capacity	Ordered capacity: 250 MW
Energy production	DH sales: 385 GWh/y
Heat losses	n.a.
Km network (double-pipe)	~ 140 km

The DH system supplies mostly residential buildings (75%) and tertiary buildings (20%), whereas the industrial sector represents less than 5%.

6.12.4. Governance and business model

Previously owned by the Municipality, Plock DH system was **fully owned and operated by Fortum Power and Heat Polska S.A. since 2005** (during the realisation of this study, it was announced that Fortum was about to sell this asset to another private company).

The DH services (heating and DHW) are offered **mainly to residential and service sector building owners** (end-customers). The offer also includes the operation and maintenance of the substations. The main objectives are to ensure a good quality service to maintain the existing customer base, but also to connect as many new buildings as possible to the DH system.

While DH basically competes with individual coal and gas heating systems, its key success factors are the **competitiveness and stability of prices**. Therefore, a DH network fuelled by an industrial **waste heat** provider has a clear competitive advantage.

New buildings (as customers) are obliged to pay a connection fee for a standard connection to the DH network. These **connection fees are submitted to an ex-ante approval** from the regulator.

The Energy Efficiency Law sets only general principles for the **allocation of heat costs** in multiapartment buildings, giving to the owners and administrators some flexibility in choosing the heat cost allocation methods. In general, the costs for heating the common parts of multiapartment buildings are divided in proportion to the floor space of occupied units. In modern residential units, individual meters are often available, allowing an accurate cost allocation reflecting the real heat consumption of each unit.

Average DH prices in Poland are about 60 €/MWh (including a VAT of 23%). The price variance among DH operators is though relatively large depending on several factors e.g., fuel sources, network density, system size and efficiency.

Tariff structures are made of 2 components (fixed and variable). Companies use the fixed fee to cover their fixed costs and the consumption-based fee to cover their variable costs. Maximum share of fixed fees for suppliers is set by the Chairman of the Energy Regulation Office (ERO).

DH tariffs in Poland are ex-ante regulated with different types of cost-based approaches which in principle are set separately for water, DH network services, heat-only-boiler production and CHP production. The tariffs are reviewed annually in a regulated process on tariff application: DHC companies prepare tariffs and the ERO accepts or rejects them.

Heat prices are set individually for every company operating in the heating sector as a function of justified costs and plans of investments. For a few years now, the Polish Energy law has allowed to include a certain rate of returns for DH network. As a consequence, **the ERO sets every year the allowed rate of returns that can be used by DH companies to establish heat tariffs**.

Even if this highly regulated approach enhances transparency of the DH companies, its stiffness sets some limits for DH operators sometimes:

- **Inflexible tariff-setting** prevents DH operators from offering customized and competitive prices (connection fees, differentiated tariffs for residential and services…) to new buildings, making other local alternative solutions more attractive.

- The tight profit scrutiny can be an **obstacle for long-term financial planning**. Thus, when new investments are needed and planned, DH operators are not always able to collect equity in advance to finance the new substantial CAPEX. In addition, as no dedicated tariff element for preparing for new RES or waste heat CAPEX is allowed, **new investments result in sharp tariff increases** which deteriorate again DH attractivity.
- **Not sufficient and predictable long-term financial incentives** (not systematically embedded in the national regulatory regime) to encourage continuous and systematic improvement of DH system efficiency and to seek for lowest cost and CO_2 content of heat sources.

6.12.5. Use of waste heat

The main drivers for increasing RES and waste heat in Plock DH system are a combination of the increased climate awareness by the society, the commitment of the local municipality to energy transition and air quality improvement, and the DH operator's vision and experience.

For Plock DH system, industrial waste heat is contracted on a yearly basis between the DH operator and the local oil refinery PKN Orlen. **The tariff and contractual clauses are discussed and agreed by the two parties, within the frame set by the national regulator ERO.** In particular, the tariff has to be approved ex-ante by the ERO.

This waste heat covers a vast majority of heat demand even though it has relatively high seasonal variance. This contractual relationship between the DH operator the third-party heat supplier has a long historical background and is a good example of a **forerunning sector integration between chemical industry and DH utilizing heat otherwise lost**.

In this case, the exported industrial heat, which results from a CHP fuelled by natural gas mostly, is a by-product of the main process plant and can be accounted as waste heat according to RED II. This waste heat is competitive against other more conventional DH sources typical in Poland like coal- and gas-CHP or heat-only boilers. Therefore, **the implementation of this solution based on industrial waste heat allowed not only to cut the CO_2 emissions down to almost zero, but also to reduce the heat cost for the end-users**.

Figure 85: Local oil refinery PKN Orlen (photo from PKN Orlen SA.)

In Poland, **the energy legislation allows third-party access for RES and excess heat provided that the DH price for end-customers does not increase and if the conditions for connection can be settled with the new third party producer**. The national specific legislation concerning TPA is mostly similar across electricity, gas and DH systems which has made the implementation and interpretations rather complex in practice. In fact, there are only few new heat sources which have entered the heat markets by using the current TPA legislation despite of several negotiation cases.

Primarily, the DH network operator has the obligation to assess the offer from the third-party supplier, and the third-party has the possibility to seek for an **external judgement from the regulator** if its offer is declined without proper technical or economic justifications. The ERO is relatively well-positioned to make this judgement because the regulator already has all the necessary financial information due to the mandatory annual tariff-setting process.

6.12.6. Sector integration approaches and local value creation

The main example of energy system integration is **the close, long-lasting heat co-operation between the oil refinery Orlen and the Plock DH system**. The DH network development is concluded in close co-operation with the City of Plock who was the sole owner of the DH network prior to selling it to Fortum in 2005.

6.12.7. Prospects

DH demand in Plock is expected to remain stable. The existing buildings will gradually improve their energy performance. **The objective of Plock DH network is to offer competitive DH to new buildings and gain a relatively high market share from this segmen**t. The competitively priced waste heat from Orlen will thus continue to be a key success factor in the future, as the competition between DH and natural gas is expected to continue.

In order to maintain high quality services and ensure competitive prices, Plock DH operator continuously makes **new investments**. Recently, these investments have been orientated toward **network efficiency improvement**, by reducing water and temperature losses. **Alternative solutions for heat production** are also assessed: CHP from biomass or RDF (Refuse-Derived Fuel) are being studied in order to anticipate the possible decline in competitivity of the current gas-CHP at the oil refinery (CO_2 taxes, RED II revision…).

6.12.8. Conclusion

Plock DH network showcases how industrial waste heat can be efficiently recovered to decarbonize the energy mix. The key success factors enabling the integration of waste heat can be summarised as follows:

i. **The geographical proximity between the DH system and large industrial players** having excess heat in order to limit the connection cost and the transmission heat losses. In the case of Plock, the historical relationship that binds the industrial plant and the Municipality also facilitates the implementation of the contract with the DH operator.

ii. **An important amount of waste heat available** in order to enable a competitive price for DH end-users and to benefit from a low carbon footprint of heating for a large part of the city's building stock.

iii. **A stable price** enabled through the use of industrial waste heat. As DH basically competes with individual coal and gas heating systems, it is a key competitive advantage to be able to provide a stable price on the long run.

iv. **The political willingness at local level to commit to energy transition and air quality improvement,** materialised by the objective of decarbonizing the DH system of the city using local and reliable heat sources.

v. **The availability of investment subsidies**. Several financial support schemes are available at national level to increase the efficiency of H&C systems and to foster the development of RES.

6.12.9. References

- Urban policy innovations in local welfare in Plock, Poland, Wilco
- Chances for Polish District Heating Systems, K. Wojdyga; M. Chorzelski; 2017

Annex 7: Technical and operational requirements

7.1. Biomass

Main biomass fuels

Table 27: Characteristics of biomass fuels

Characteristic	Wood chips	Wood pellets	Miscanthus	Wood waste	Wood industry residues
Picture	 (Source: ETIP Bioenergy)	 (Source: www.dhnet.be)	 (Source: miscanthus.cfans.umn.ed)	 (Source: Midi Pyrénées Bois)	 (Source: Midi Pyrénées Bois)
Description	**Most used fuel** in biomass boilers **Made by grinding wood from forest management** (branches and parts that cannot be valorised in lumber or crushing industry) **Also made from short rotation coppice** such as willow, planted and harvested for heating applications	**Made from sawdust wood**, powdered and **raised at high temperature and pressure**. The lignin (wood component) melt during the process and act like a resin, binding particles together into small cylinders.	**Woody rhizomatous grass.** Its properties make it a good biomass fuel Other agricultural waste can also be considered (e.g. grain and crop residues).	Composed by **end-of-life wood** (wood from waste sector). To be accepted as fuel, **the wood must not be treated nor soiled.** A good traceability and **quality control** are required for suppliers. It can be, for example, pallets or crates.	Products related to first transformation of wood. Comes from **sawmill byproducts.** Mix of bark, sawdust, shaving, grind and offcut.
Advantages and drawbacks	**Easy to use** for biomass boilers. There is a high **competition for the use** with other wood industries.	**High-performance fuel** with very low moisture content and very high density. **Easy to manipulate. More expensive than wood chips** due to the manufacturing process.	**High heating value.** Can easily be planted and harvested.	**Relatively cheap** fuel. The major problem is the **heterogeneousness**	**Cheaper** than wood chips or wood pellets. High ash content. Moisture content and granulometry **can vary significantly from a sample to another.** Subject to **competition for the use** with crushing industries.

Heating value or calorific value[51]	3.5 kWh/kg	4.8 kWh/kg	3.6 kWh/kg	5.8 kWh/kg	4 to 6 kWh/kg
Moisture content[52]	40% to 60% (can drop to 20% after storing and drying for at least 4 months)	< 10%	15%	20 to 30%	20 to 65 %
Ash content[53]	1 to 3%	< 2%	3%	Depends on the source	1 to 3%
Density[54]	250 kg/m^3	650 kg/m^3	140 to 180 kg/m^3	Depends on the source	480 to 640 kg/m^3

The fuel can be classified by a **granulometry class**, defined in the European norm EN ISO 14961. It represents a distribution of the size of wood particulates composing the fuel. The fuels can have variable granulometry classes. The different classes possible are P16, P31, P45, P63 and P100. For example, if the fuel is P16, it means that more than 80% of particulates have a size lower than 16 mm.

The preparation of the fuel is made by grinding the resource into a certain granulometry class, cleaning it from impurities, and then drying and storing. The granulometry impacts the combustion rate.

Combustion and types of biomass boilers

To initiate a combustion the fuel needs to be mixed with air at the convenient level of temperature and pressure. **The combustion of biomass goes through several stages when the temperature grows**. At first, when the temperature begins to increase, it **dries** the fuel by making the water content evaporate. Then, the different **compounds of the wood decompose** at different temperature levels (first hemicellulose, then cellulose, and finally the more stable, the lignin). When all these compounds are burnt, **it remains ashes** which are unburned carbon residues. The flames come from the radiation of the burning soot.

The principle of combustion in an industrial boiler is to **reduce the amount of remaining ashes as much as possible to benefit from the best amount of energy possible**. To do so, air flows are adjusted to the combustion parameters. A **primary air flow** enables to mix air with the fuel and favour the convection of the first stage. The flow must not be too important to avoid inhibiting the initiation of the combustion process. A **secondary air flow** passes in the upper part of the boiler where flue gas will be ejected. The remaining unburned compounds of the flue gas can thus react. This flow is important to reduce emissions of pollutant and enables to benefit from more combustion energy. The repartition of the air flows is generally 40% for the primary flow and 60% for the secondary flow. Different forms of air injection exist to adapt to the boiler, the aim is to mix air with fuel as well as possible.

To recover the heat from the combustion process, two methods exist:

[51] The heating value is the amount of energy produced during the combustion of a kilogram of fuel. **The heating value depends directly on the moisture content of the fuel**. The more the moisture content, the lower the heating value.
[52] The moisture content is the proportion of water in the fuel.
[53] The ash content is the mass of bottom ash remaining after the combustion with respect to the initial mass of the fuel.
[54] The density represents the compactness, i.e. the mass per unit of volume. It depends on the moisture content of the fuel. The density presented in this table is the average anhydrous density. Source: Forest, "A guide to specifying biomass heating systems," 2012.

Fire tube exchanger: the flue gases at high temperature pass into tubes. These tubes, immersed in a water tank, exchange the heat with water. The heated water is then used in the heat distribution system.

Water tube exchanger: The water of the distribution system passes into tubes that are into the combustion chamber. They are heated by the flue gases at high temperature.

Four types of boiler can be used (see Figure 86). **Stocker burner boilers** have a small grate capable of a fast response to heating demands. They accept fuel with a moisture content up to 30%. If there is only one ventilation fan, it may be difficult to separate primary and secondary air and it could cause slag formation. To avoid this risk, a water-cooling circuit can be set in the grate. In **underfed stocker boilers**, the fuel is pushed from beneath the combustion chamber. They also accept fuel with a moisture content up to 30%, and have fast response to demands.

Moving grate boilers offer a greater flexibility in the design. They can accept fuel with moisture content up to 50% thanks to a refractory lining. Flue gas recirculation is essential to limit the combustion temperature when burning dry fuels (below 20% of moisture content) and also has the advantage to lower the percentage of oxygen in the combustion air/flue gas mixture, thereby reducing thermal NOx formation. However, they have a slower response to demands.

Bubbling fluidized bed boilers accept a wide range of fuel with a moisture content up to 65%. It is adapted to high power installations. The principle is to have a bed of particulates being crossed by an upward air flow allowing the mix to behave as a fluid. The air flow is controlled to enable an efficient mixing with keeping the particles in the fluidized bed.

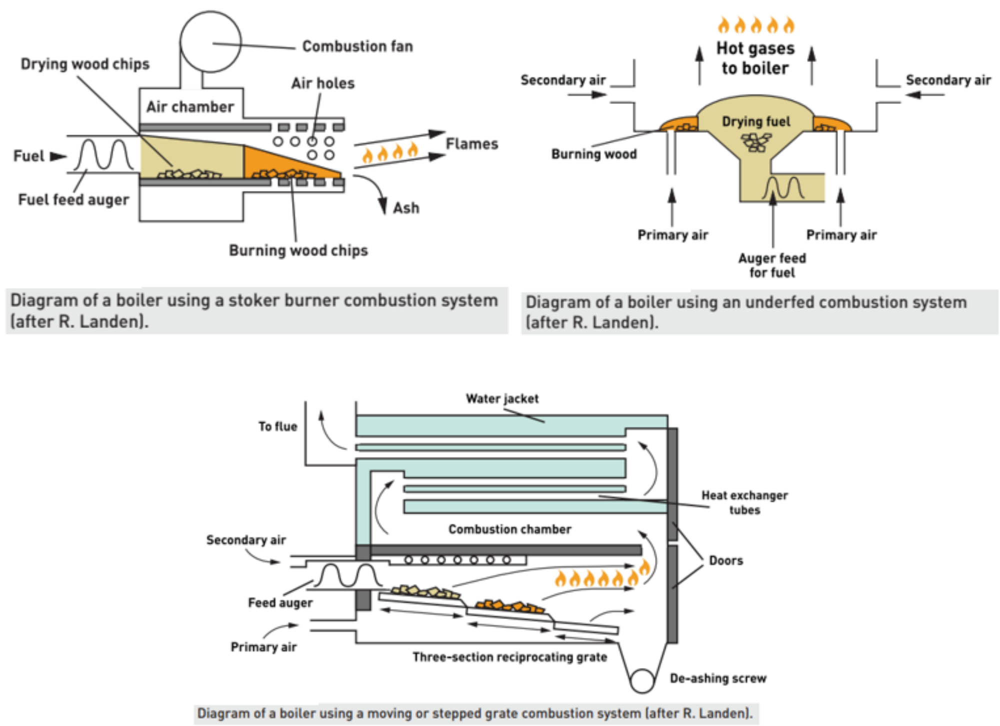


Diagram of a boiler using a stoker burner combustion system (after R. Landen).

Diagram of a boiler using an underfed combustion system (after R. Landen).

Diagram of a boiler using a moving or stepped grate combustion system (after R. Landen).

Figure 86: Types of boiler (Source: Department of Energy and Climate Change & Forestry Commission of Scotland, 2011)

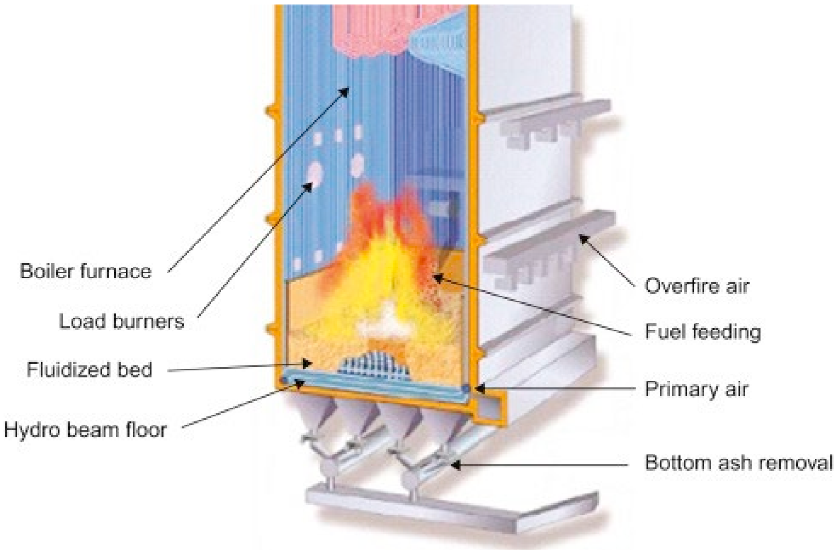
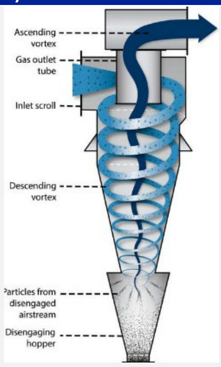
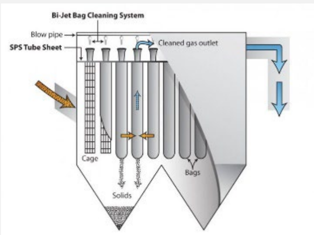
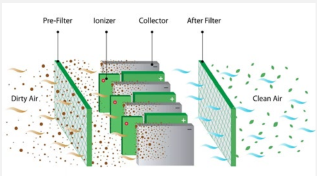
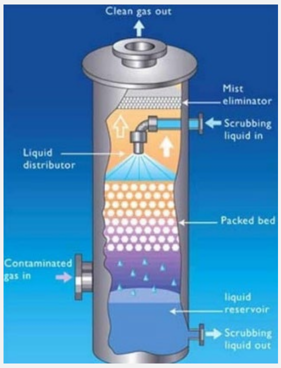


Figure 87: Bubbling fluidized bed boiler (Source: Dipak K. 2015)

Particulate filters

Different types of particulates filters are presented in the table below.

Table 28: Description of the different types of particulate filters

	Cyclone	Bag filter	Electrostatic filter	Wet scrubber
Picture	 (Source: Direct Industry)	 (Source: Thermodyne Engineering systems)	 (Source: HowtoHome)	 (Source: Indiamart)
Description	Particulates are driven towards the bottom by the **centrifugal force** of the rotating flow.	The flow passes through the bags that behave like **sieves** retaining particulates.	Particulates are retained by an **electrostatic field**.	The flow passes through a water injector. The **water droplets capture particulates**.

Advantages	Captures particulates down to 20µm.	Captures particulates down to 1µm and most of PM10 and PM2.5 particulates.	Captures particulates down to ultrafine particles (smaller than PM2.5).	Captures particulates down to ultrafine particles (smaller than PM2.5). Dissolves CO_2 and NO_2 gases.
Drawbacks	Does not capture PM10 particulates.	Requires regular maintenance. Can be damaged if it supports the biggest load of particulates, so it must be placed after another filter.	Must be placed after another filter.	Must be placed after another filter. Produces weak acid when gases dissolve.

7.2. Geothermal energy

Wells and probes design

The well design takes into consideration geological and hydrogeological conditions, groundwater quality, and drilling methods. A well must not degrade the ground conditions. Casing size is based on the needs, the bore screen length, and the drilling diameter.

A representative graphic of a well structure is provided below (see Figure 88). The water enters the well through the bore screen. Two different design of pump can be chosen: a line shaft pump which has the motor at the surface, or a submersible pump which is completely underground, inside the well. A submersible pump is the most common for DH application. At the surface, distribution pipelines are connected.

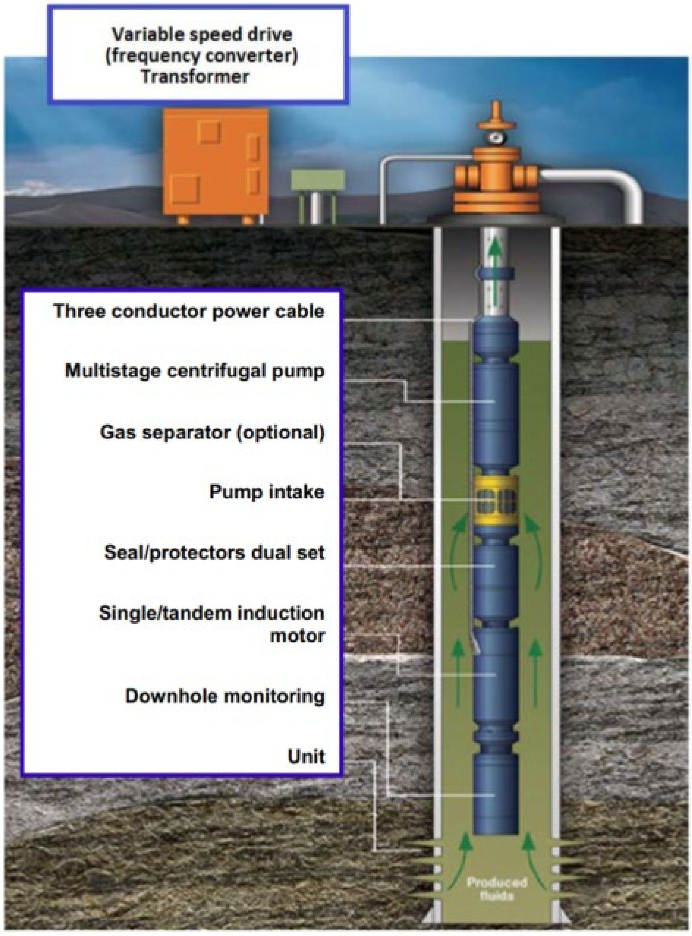


Figure 88: Schematic representation of typical Electrosubmersible Pump (ESP) string (Source: Schlumberger, 2015)

An artesian aquifer is an aquifer with a pressure greater than the atmospheric pressure. It implies that if a well connects these two pressures, groundwater tends to move up to the surface freely without any pumping needs. In this case the priority of the well is to control the pressure and the resulting flow.

For a reinjection well, it is common to place a line shaft pump in order to give to the fluid the necessary pressure to be reinjected.

As far as probe fields are concerned, different probe configurations are possible (see Figure 89). U-probes are the most common, in one borehole there can be up to 4 U-probes, increasing the efficiency. Probes usual diameters are DN 25, DN 32 and DN 40

(Nominal diameters of 25, 32 and 40 mm respectively). They are made of plastic material (PE) which is a high-density polyethylene and is very resistant.

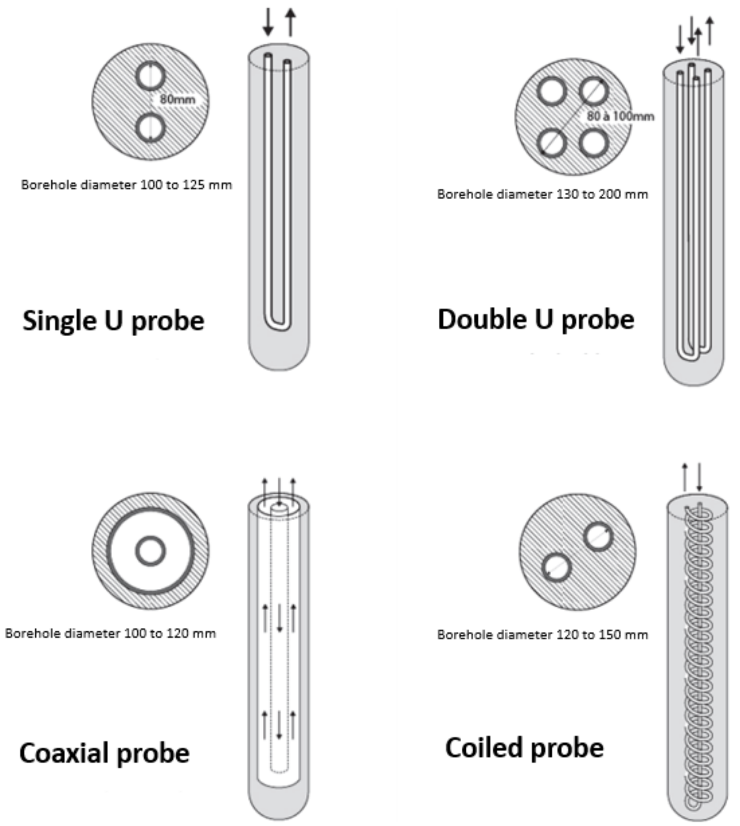
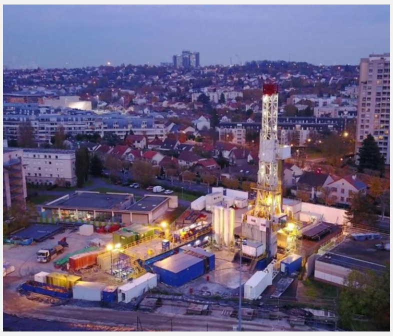


Figure 89: Probe configurations (Source: ADEME, “Les pompes à chaleur géothermiques sur champ de sondes,” 2012)

Drilling methods

Drilling is a sensitive operation and must be carried out by experts as it can impact the rest of the geothermal operation and the ground structure. Geological and hydrogeological conditions are taken into account. In the case of a multiple aquifers ground it is important to ensure that water from different aquifers do not mix. Different drilling methods are possible.

Table 29: Description of drilling methods

Method	Picture	Description	Application	Advantages - Drawbacks
Rotary	 (Source: Dalkia, 2018)	A drill bit at the end of the drill pipe **rotates and translates** into the ground. The drill bit can be a tricone or a core drill. The **direct method** enables to reject mud to the surface through the annulus between the borehole and the drill pipe. When the drill diameter is big, the **reverse method** is used and the rejected must pass into the drill pipe.	This method is used for geothermal heat production from aquifer.	The drill bit can be adapted to the hardness of the ground. It requires a fluid to cool the drill bit and remove the cuttings. It is usually mud (water or air are used for shallowest prospects).
Percussion	 (Source: Massenza Drilling rigs)	A percussion device is used to dig with a **hammering method hold by cables**.	This method is used for geothermal heat production from probe fields.	Slow operation with a limited depth.
Roto-percussion	 (Source: Marini Quaries Group)	This drilling method includes **movements of rotation and percussion**. The drilling tool is a **jackhammer or a hydraulic hammer powered by compressed air**.	This method is used for geothermal heat production from probe fields.	Fits with cohesive soils. It can reach important depth and follow precisely the ground structure. It is a very fast method. It can be blocked when the soil is dry or not cohesive enough.

Before choosing the drilling method a geological and hydrogeological studies are carried out. This study points out the difficulties for drilling and the main rocks present in the ground. It will impact the choice of the method as they are not adapted to all type of rocks.

7.3. Biogas

Methane potential of different types of input

The methane potential represents the amount of methane generated during the anaerobic degradation of an organic matter. It depends on the input. Values for different inputs are presented in the table below.

Table 30: Methane potential of different inputs (source: ADEME, Aile, Solagro, Trame)

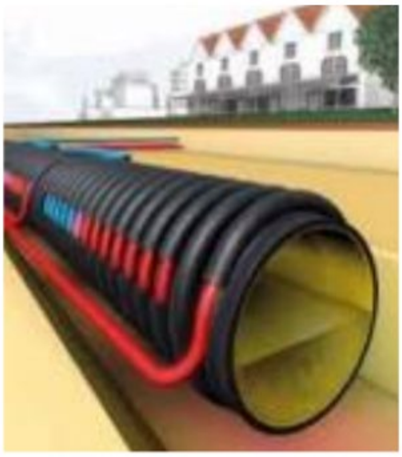
Type of input	Input	Methane potential (in m^3 of CH_4/t of raw material)
Agricultural waste and manure	Potato pulp	50
	Husk	150
	Corn residues	150
	Cereal residues	300
	Colza cake	350
	Liquid bovine manure	20
	Bovine manure	40
	Poultry manure	60
Food industry waste	Gut content	30
	Brewery waste	80
	Slaughterhouse grease	180
	Molasses	280
Urban waste	Used grease	250
	Sludge from waste water treatment plants	40
	Domestic organic waste	70
	Lawn	130
	Grease from waste water treatment plants	240

7.4. Ambient energy

Different models of in-sewer heat exchangers

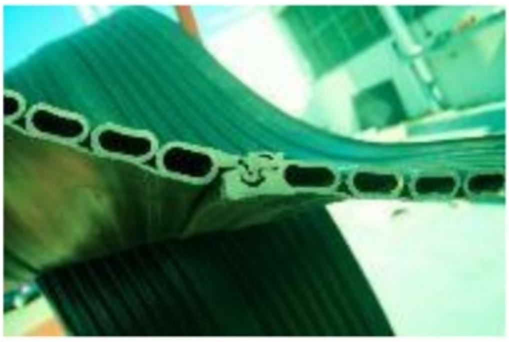
In-sewer heat exchangers are specific to waste water heat recovery application. Several designs exist. An overview of some models is presented in Figure 90.

Source: Huber technology



Source: Frank (PKS Thermpipe)

Source: Rabtherm



Source: Branderburger Liner

Figure 90: Examples of in-sewer heat exchanger models

7.5. Connection to district energy systems by third party suppliers

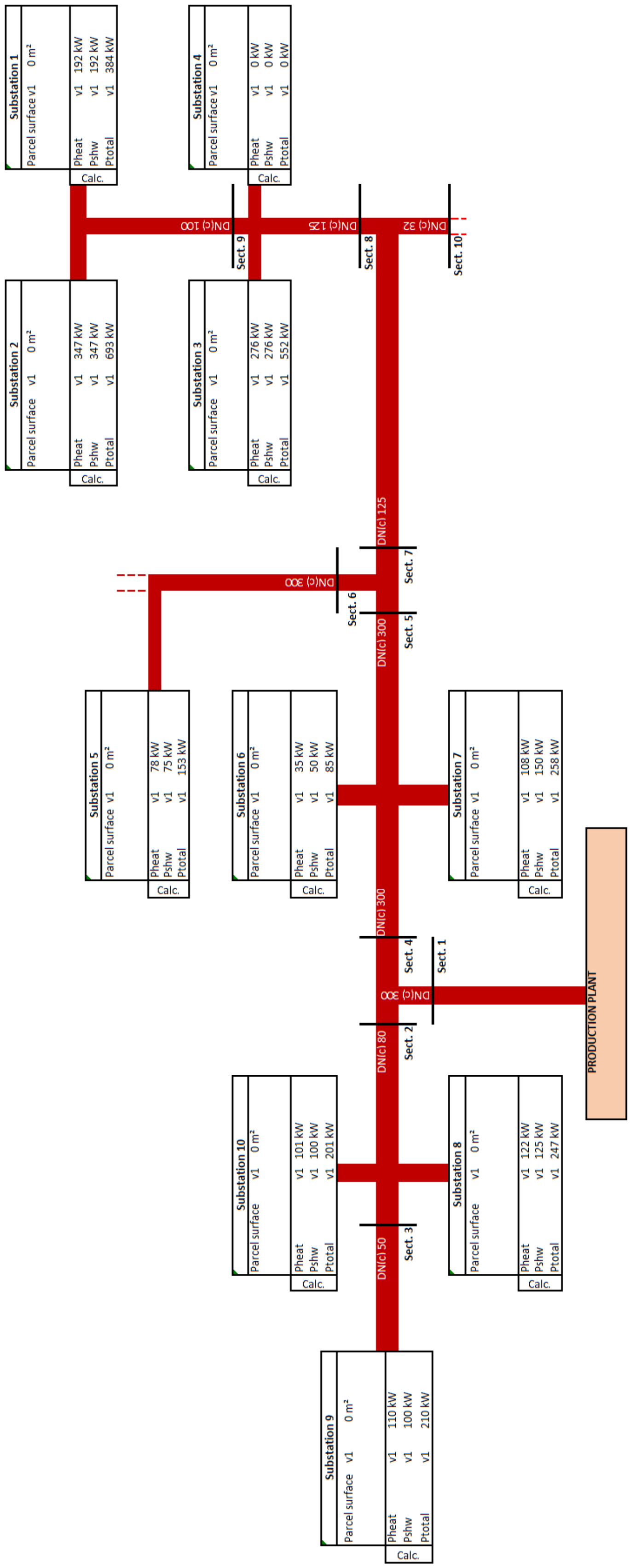


Figure 91: Simplified example of synoptic built for network design (Source: own resource)

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