FROM WASTE HEAT TO USABLE HEAT

Connecting data centers and district heating networks

Distributing, organizing, and financing the reuse of waste heat from data centers in heat networks will become more accessible thanks to some convergent trends in both sectors, as they aim to achieve higher sustainability and decarbonization levels. This whitepaper was created in collaboration with Grundfos.

Executive Summary

This document outlines the challenges and benefits of upgrading waste heat from data centers to usable heat distributed by district heating networks.

Both the data center and district heating sectors are expected to grow significantly in the next two decades, and both are under pressure to reduce their carbon footprint and improve their sustainability. This whitepaper provides high-level figures on the size of both sectors, the district heating market penetration in Europe, and the typical fuel types used in the district heating market, highlighting the dominance of fossil fuels in this market.

The policy landscape for reusing waste heat is becoming more favorable, supported by European institutions such as Euroheat & Power (heat networks association) and the Climate Neutral Data Center Pact.

The second part of this whitepaper presents a technical examination of the quantities of waste heat available from data centers, their suitability for use in heat networks, and how supply can fit the demand curves.

Another topic discussed is the range of temperatures in the heat networks, how they impact efficiency and network topologies, and how local needs can be optimized by the integration of heating plants.

The distance between data centers and heat network affects the feasibility of a heat reuse project. While the impact of distance on the operations and overall efficiency is limited and can be minimized by good practice and design, multi-kilometer connections can have a significant impact on the total investment cost.

Because of their expertise, understanding of regulations and standards, and efficiencies of scale, heat network operators are the preferred project leaders but ESCOs come a close second and may have an advantage in terms of agility and ability to raise the necessary financing.

The normal model involves the data center delivering waste heat to a heating plant, owned and operated by a heat supplier who works closely with a heat network operator, but the model may vary depending on the location, stakeholders, and their motivation.

To test the viability of heat reuse from a data center, a business case was considered based on a 10 MW IT load. Three heat reuse connection types (classic, COP efficient, and booster) were defined to examine the project's viability in terms of efficiency, usable heat price, and heat network temperatures.

As a discussion point, each connection type was compared with a standalone heat pump. The results were as follows: The “classic” connection type provided savings of approximately €0.5M, effectively reducing the marginal heat generation costs from €30/MWh to €23/MWh.

However, the most efficient solutions may not always be the most beneficial in terms of economic outcomes. In the models examined, the net cash flow for the least efficient connection type (“booster”) is the greatest, with a simple payback period of approximately 9 years.

This paper confirms that there is benefit to both industries by linking data centers to heat networks. To increase the viability of these projects, we encourage data centers to engage early, share information, and actively collaborate with local authorities and heat network operators to influence the planning and development of sustainable infrastructure.

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Sector Coupling Overview

Working towards net-zero and improved energy efficiency, the two energy-intensive sectors, data centers and district heating, are expected to grow significantly in the coming years. Coupling data centers with heat networks may reduce society's carbon footprint significantly. Reusing heat from all European data centers could save more than 10 million tons of CO_2 annually.

The data center sector is evolving rapidly, with flexibility and agility being its main characteristics and short technological cycles forcing decisions with short payback times. District heating networks operate in highly regulated environments, with long-term planning and low, but certain rates of return on investments. Both sectors face sustainability pressures: data centers being scrutinized for their large electricity consumption and the associated waste heat generation, and heat networks for using fossil fuels. However, the environmental impact of both sectors can be significantly lowered if the waste heat from data centers were reused in district heating networks, effectively helping to decarbonize the heat networks.

Energy Consumption of Data Centers

Data centers are the backbone of the internet and data processing. Recent regulations requiring local data storage and processing are driving a shift from the historic data center hubs such as Frankfurt, London, Amsterdam, and Paris (FLAP) to a more proportional geographical distribution of the market.

Data center energy efficiency keeps improving, with the average PUE for global data centers falling from 2.0 to below 1.6 in the years 2010-2020[1], with hyperscale data centers achieving values of around 1.2. However, the overall EU data center energy consumption almost doubled between 2010 and 2020, from 54 to 104 TWh/a, due to the increase in data processing. This is expected to grow to 160 TWh/a by 2030[2] even with the above-mentioned improvement in energy efficiency.[3]

Heat Network Overview

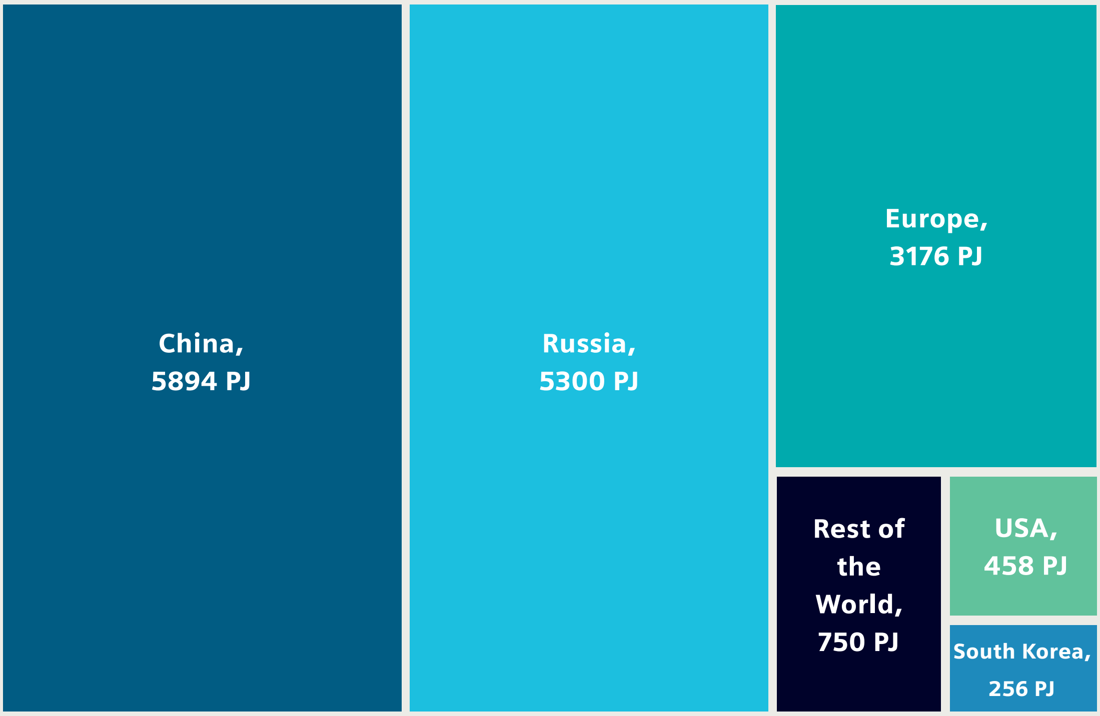
District heating networks provide multiple users with heat for space heating and domestic hot water. Each network has a pipeline with a higher temperature feed or flow pipeline, and a lower temperature return pipeline, with water returned to the heating plant for reheating.

Moving the heat generation process from individual buildings to centralized heating plants allows for efficiencies of scale in terms of energy consumption, pollution control, and peak shaving. On the downside, heat distribution is associated with heat losses and requires additional capital investment and ongoing maintenance.

Europe is one of the largest district heating markets with 3,176 PJ (1,045 TWh) of heat delivered annually, following China and Russia, which account for more than 70% of the global footprint (see Figure 1). The US is a relatively small market with 458 PJ (127 TWh).

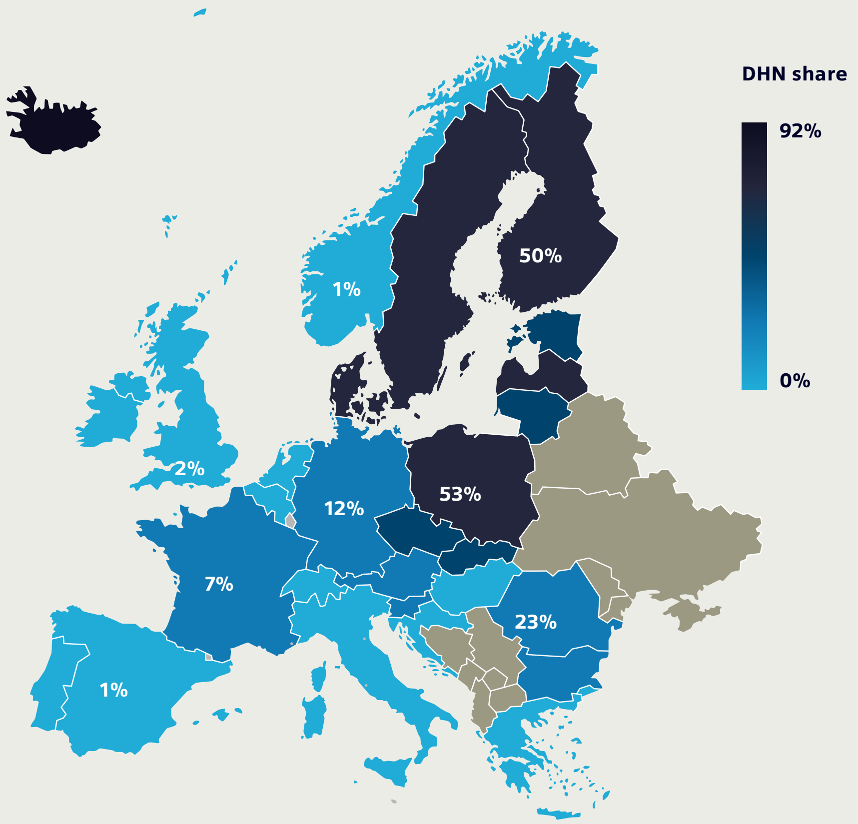
Within Europe, the highest share of heating provided by heat networks is Iceland (92% of total heat demand). Very high shares, above 50%, can be found in the Nordics (excluding Norway), the Baltic countries and Poland, while Greece and Portugal have shares of less than 1% as per Figure 2.

Figure 1 – Heat delivered via DHN markets



Heat networks can vary in scale. Some of these DHNs cover entire urban areas, with hundreds of kilometers of pipelines. Three of the largest systems are in Warsaw, Copenhagen, and Stockholm, with total lengths close to 1,500 km, delivering gigawatts of heat. Other schemes cover smaller districts, amounting to tens of kilometers in length, from which the English term "district heating" was derived, to local heat networks in villages, to campuses (universities and airports) which can be just a few kilometers long and have total installed capacities below ten megawatts.

Figure 2 – Share of DHNs in total heating demand



Heat Network Trends

Climate change and decarbonization were not top of the agenda for the promoters of traditional heat networks, and most existing networks are fueled by fossil fuels, making up 76% of the EU's primary energy in heat networks. Biomass, domestic and industrial waste are growing sources of fuel, with shares of 19% and 5% respectively[4]. Many networks integrate combined heat and power generation to increase efficiency and improve air quality.

The investment in district heating networks is expected to grow significantly for various reasons.

The increase in heat demand, the need to retrofit aging assets, the introduction of energy efficiency initiatives, and the drive towards decarbonization, all contribute to this investment demand.

According to Heat Roadmap Europe[3], district heating capacity is expected to double by 2050, adding 160 TWh/a of capacity per decade. The growth in DHNs' capacity is in line with the forecast growth in energy consumption by EU data centers over this period. The growth in both sectors presents significant opportunities for DHNs to absorb the growth in waste heat generated by the data center industry across the EU.

The decarbonization of heat networks is a complex task, and progress has been slow due to uncertainty around CO_2 emission costs and fuel prices. Meanwhile, operators' investment budgets have been stretched by projects aimed at meeting pollutant emission limits.

Renewable heat generation and efficiency targets combined with fuel and electricity price trends are important drivers for the decarbonization of heat networks. However, until recently, they were insufficient to promote substantial change in the industry.

Fossil fuels are the predominant energy source for district heating schemes, accounting for three quarters of the total supply, with biomass and renewable waste accounting for 20%, and other renewables and electricity making up the remaining 5%[4], illustrated in Figures 3 and Figure 4.

With the increasing integration of renewable energy sources and the increased focus on sustainability and waste reduction policies, it is plausible that 80-90% of the existing heat plants and networks will require a deep retrofit.

Figure 3 – Fuel mixes for DHNs in EEA countries

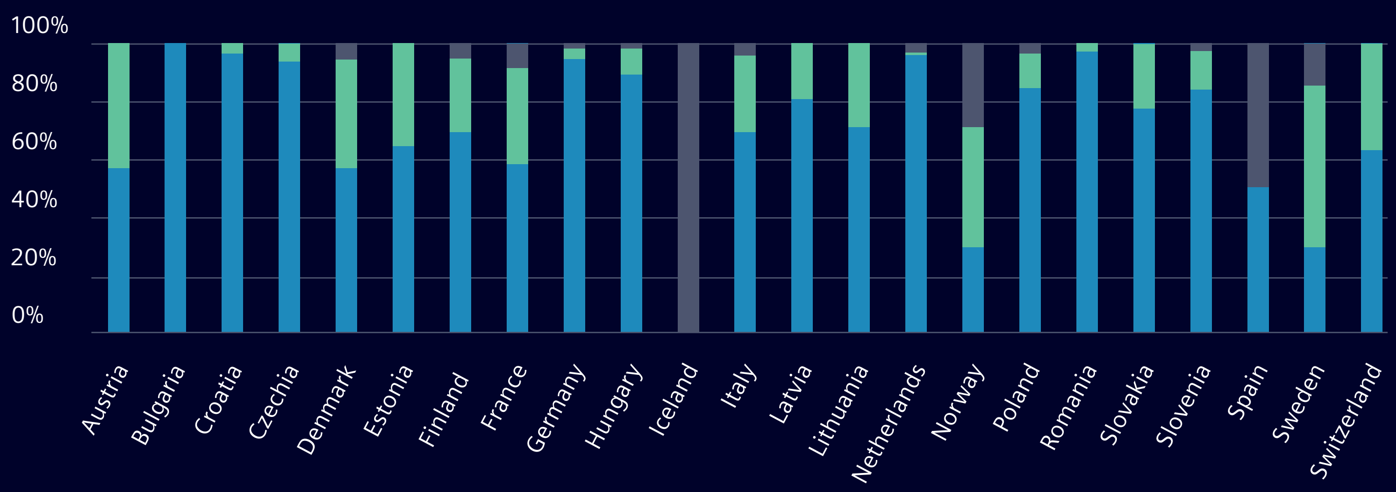
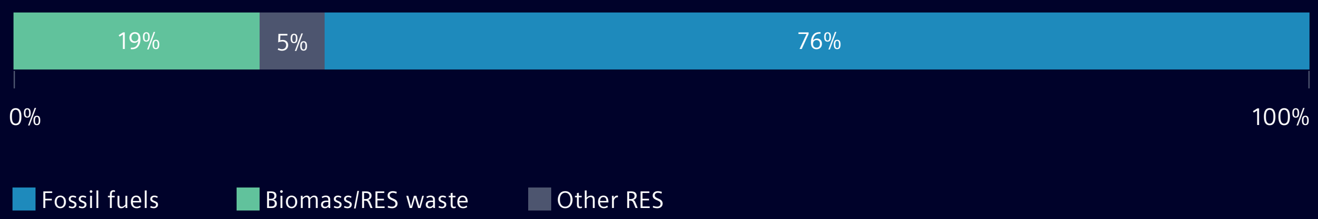


Figure 4 – Heat network fuel mix combined across EEA



Heat network operators need to keep the cost of heat supply low and make use of emissions trading schemes to enable them to compete with individual heating systems that are exempt from emissions trading. The improved energy efficiency of buildings connected to heat networks reduces the revenue from existing connections, often affecting the network's ability to raise the investment capital needed to expand and decarbonize heat generation networks. However, the building efficiency increase can also provide efficiency gains where supply and return temperatures can be lowered, thereby resulting in reduced heat losses. This allows the HNO to expand the heat network without additional production capacity. As such, modern technological solutions, where temperatures are managed to meet the exact consumer demands in a decentralized way, could open more possibilities for renewable production or the use of waste heat.

These trends can be offset by the availability of preferential financing from research or environmental agencies, but for most heat networks, systemic changes will be needed to enable the growth and decarbonization required by the EU.

One such policy, the "Fit for 55" package, will create a mechanism compelling the building sector to pay for CO_2 emissions, leveling the playing field for heat networks.

The objective of this package is to combine waste heat reuse with renewable energy, setting a target 2.1 % annual increase for renewable and waste-heat energy sources[4], resulting in electric heat pumps delivering most of the heat in the EU by 2050.

Funding and support will continue to be linked with the "efficient district heating and cooling system" yet to be defined and replace co-generation with higher renewable and waste heat usage[5]. Heat reuse from data centers is specifically mentioned and will receive support in upcoming regulations.

Similarly, the EU's Green Finance Taxonomy lists all the related topics as sustainable, including the production of usable heat using waste heat, district heating distribution, installation, and the operation of electric heat pumps.

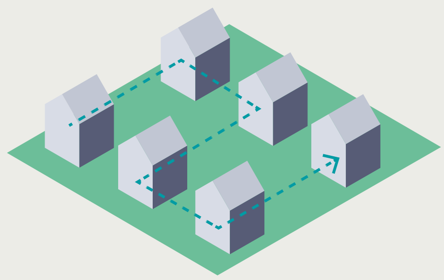
Support for Heat Reuse

Associations and bodies from both sectors voiced their support of heat reuse from data centers in support of the decarbonization agenda. Euroheat & Power, a European network of district heating organizations which includes Siemens and Grundfos among its members, published a policy paper in May 2021 calling on the EU to recognize data center heat recovery in EU frameworks, boost skills training, and integrate heat reuse in guidelines for the data center industry[6].

Some of the recommendations are already materializing in the "Fit for 55" package and the 2021 Best Practice Guidelines[7] published by the European Community's JRC and the EU Green Public Procurement Criteria guidelines[1]. The Climate Neutral Data Center Pact is a pledge by 22 national trade associations and 60 individual members to achieve climate neutrality in European data centers by 2030. One of its areas of focus is to promote regulations on data center sustainability. The pact pledges to explore the possibilities of exporting data center waste heat for reuse in heat networks and calls on policymakers to:

1 Recognize recovered and reused heat as an energy source that reduces emissions for real-estate developers, building owners, and other stakeholders.

2 Enact a policy framework that facilitates and encourages any energy-intensive industry to pursue heat recovery and reuse projects in partnership with communities or businesses[8].



Technical Considerations

Most of the power consumed by the IT equipment in data centers is converted into heat, and that heat needs to be removed to enable the equipment to function properly.

A variety of cooling technologies are used to keep the electronic components in data centers operating within acceptable temperature and humidity ranges. Regardless of the type of cooling systems – direct expansion CRAC units, chilled water fed CRAH units, or evaporative cooling – significant amounts of low-grade waste heat needs to be dissipated.

Most of the waste heat is in the 20-26°C temperature range[9]. Waste heat in this temperature range has a limited number of applications, such as heating of swimming pools or aquaculture farms.

These applications are relatively sparse and have a low total heat demand compared to the amount of heat generated in a modern data center. For most data centers, the opportunity to export their waste heat is limited due to the higher temperature requirements of the potential users, resulting in the need to upgrade this heat using heat pumps.

Five key technical factors to be considered for heat reuse are:

- Heat pump technology limitations
- Heat network temperatures
- Connection options
- Heat network demand profiles and existing assets
- Distance from the heat network

Heat Pump Limitations

Heat pumps use refrigerants in a refrigeration cycle, where electric power is used to compress the gas and elevate the refrigerant fluid's temperature. The principle is similar to CRACs and chillers widely used in data center cooling.

There are thermodynamic limits to the efficiency of heat pumps associated with the temperature difference between the evaporator (the cooling part) and the condenser (the heating part). The bigger this delta T, the more electricity isrequired relative to the amount of heat generated. The efficiency of heat pumps is called Coefficient of Performance (COP) – useful heat delivered divided by the power consumed.

COP values depend on the temperature difference between the heat source and heat sink. The heat source in this case is the data center where higher temperatures are preferred, and the latter is the heat network where lower temperatures are preferred.

In most cases of heat reuse, the COP of the heat pump falls within the range of 3.0 to 6.0. That means that from each kWh of electric power used for heat upgrade, three to six kWhs of useful heat is generated by the heat pump.

Heat Network Temperatures

The maximum, the average and the return temperatures in a heat network affect the efficiency of the heat upgrade when using heat pumps. The operating temperatures of heat networks vary considerably, depending on the network's age, the client's needs, and the technologies used.

The evolution of heat networks has resulted in the continuous reduction of the networks' operating temperatures. First-generation (1G) networks operated at approximately 200°C, second-generation networks (2G), which are predominant in Central Europe, operate at 100-120°C, while the third-generation networks favored in Nordic countries operate at 80-100°C.

Modern (4G) networks have been specifically developed to make use of renewable low-grade heat sources, such as solar and geothermal, operating with flow temperatures well below 70°C. These networks are suitable for utilizing waste heat from data centers.

The latest (5G) networks are an emerging concept where water at 10-25°C is used as the base load for efficient heat pump operation, without the need for ground source heat pumps and geothermal wells, but they are out of scope for this document. Larger existing grids can be divided into temperature zones with different heat demands. When designing or renovating grids, the zones should be optimized to deliver the temperature required at the point of use, thus resulting in reduced heat losses and the ability to utilize locally generated waste heat.

Heat Network Generation	**1st**	**2nd**	**3rd**	**4th**	**5th**
Flow temperature	120-200°C	100-120°C (130°C)	80-100°C	(50) 60-80°C	10-25°C
Return temperature	100-140°C	80-110°C	60-90°C	40-70°C	3-15°C
Typical heat sources	Steam boilers	CHPs , boilers	CHPs, boilers, geothermal	Heat pumps, geothermal, solar	Waste heat, geothermal, solar

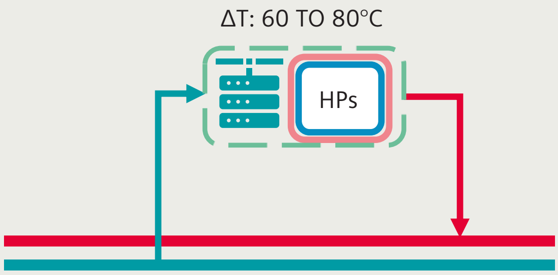
Table 1 – Typical temperatures for generations of heat networks

Network Connection Options

Depending on the topology of the heat network, its operator might have preferences regarding the way the heat is supplied:

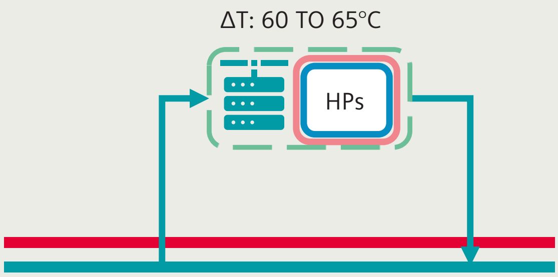
Figure 5 – Options for connecting the heat upgrade plant to the heat network

Classic: Return to feed
a) The waste heat reuse plant is expected to be the main source of heat for the scheme. It needs to operate in the “classic” paradigm of heating up the water from the return to the flow pipeline.



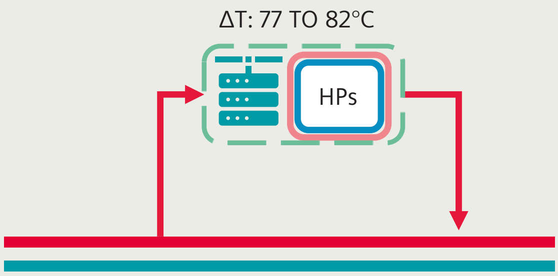
(a) Classic: Return to feed

Efficient: Return to return
b) When connecting to larger systems, HN operators may choose to maximize the efficiency of heat recovery and accept lower-grade heat into the return pipework.



(b) Efficient: Return to return

Booster: Feed to feed
c) Boosting the temperature locally, at the far edge of the network, might allow for lowering temperatures in the remaining parts of the network, leading to overall system efficiency improvement.



(c) Booster: Feed to feed

As the temperatures in networks often change seasonally, it is possible to deliver the “classic” mode in the summer and switch to “COP efficient” mode in the winter when flow temperatures increase. Each network may have slightly different expectations and boundary conditions, which can be reflected in the heat prices. Heat supplied to the DHN is often bought using dynamic tariffs depending on outdoor temperatures and connection parameters.

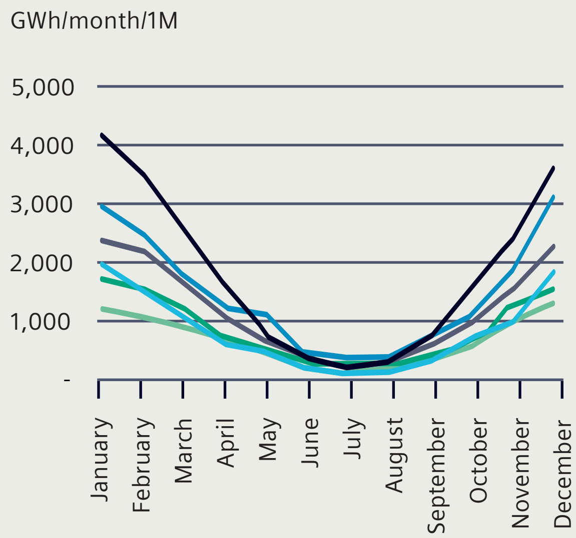
Heat Network Demand Profiles

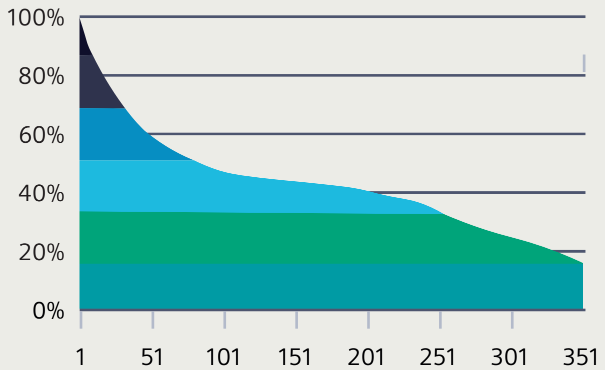
Heat networks provide heating for multiple purposes: space heating, sanitary hot water, and sometimes process heat for industry. Besides the efficiency of the system, the other critical factor for heat reuse is the ability of the network to absorb the usable heat and utilize it. Large data centers generate more heat than many district heating networks could distribute.

Heat networks are usually fed from multiple sources, such as CHP plants, boilers, and heat pumps, with the base load provided by the most efficient source throughout the year, and the least efficient source topping up when heat demand is at its peak. Ideally, the base load source should operate for as long as possible to provide a steady supply. In the case of a data center operating constantly, it can meet the summer base load for sanitary hot water, with the network drawing in other sources as the demand for heating increases.

When examining heat demand profiles per million inhabitants, the difference in demand is greater in colder climates than in warmer climates. For example, in Helsinki the summer demand is only 5% of the winter demand, compared to milder regions such as London or Madrid where the summer demand is 20% of the winter demand as seen in Figure 6. Using examples from Denmark where domestic hot water production by DH is more cost efficient than production by electricity, the summer demand may be as high as 30% of the winter demand.

Accurate data on heat demand in networks is difficult to obtain, but research shows that typical heat networks have 30-60% more capacity than their peak demand, to cover for safety of supply and redundancy. The demand profile follows the local climate conditions.





Madrid | London | Berlin
Brussels | Stockholm | Helsinki

Figure 6 – Heat demand profiles for select European cities[10]

Figure 7 – Example of a load duration curve of a heat network

Distance from the Heat Network

Distance can have a big impact on the investment costs. The ratio of the connection costs can increase from 3 to 50% of total CAPEX when the distance increases from 50 to 4,000 m.

It is important to point out that while civil engineering, including excavation and pipelines, constitutes more than half of the typical pipeline costs, other factors such as securing pipeline routes, road closures and locating auxiliary equipment could be challenging, especially in densely populated areas with multiple stakeholders, such as landowners, infrastructure operators, and local authorities. Conversely, densely populated areas are beneficial for heat networks since a significant amount of energy is distributed in a small geographical area, thereby resulting in a low operating cost.

The distance between the data center and the heat network also impacts pump selection, running costs, energy consumption, heat losses, and maintenance. Apart from the capital cost of the pipeline, these other costs are acceptable.

A well-insulated, correctly sized pipeline in a 70-80°C system will have moderate friction losses, and the heat loss will be 0.5-1.5% per kilometer[11]. The heat losses can be further reduced by recirculating the waste heat and upgrading the heat closer to the DHN. This can reduce heat losses by a factor of 3 or 4 (Figure 8, Option B). In addition, this configuration allows for the use of cheaper polyethylene (PE) pipes due to the lower operating temperatures. As such, the distance between the waste heat source and the point of use should be evaluated for the optimal placement for the heat upgrade asset. Two options can be considered for connecting data centers to district heat networks, as illustrated in Figure 8:

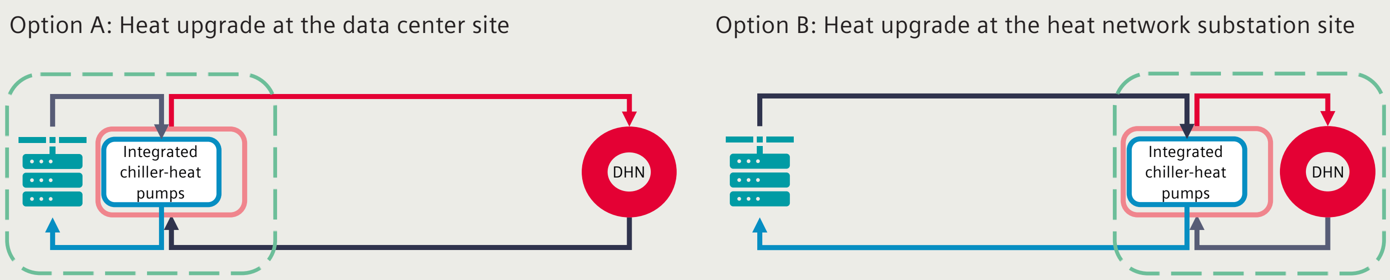


Figure 8 – Connector options: on-site and at the substation

Commercial Considerations

Project Stakeholders

A heat reuse project is a complex undertaking. As access to heat is considered a basic necessity, the market is regulated, with arduous reporting and monitoring requirements, operated on thin margins, and reliant on subsidies.

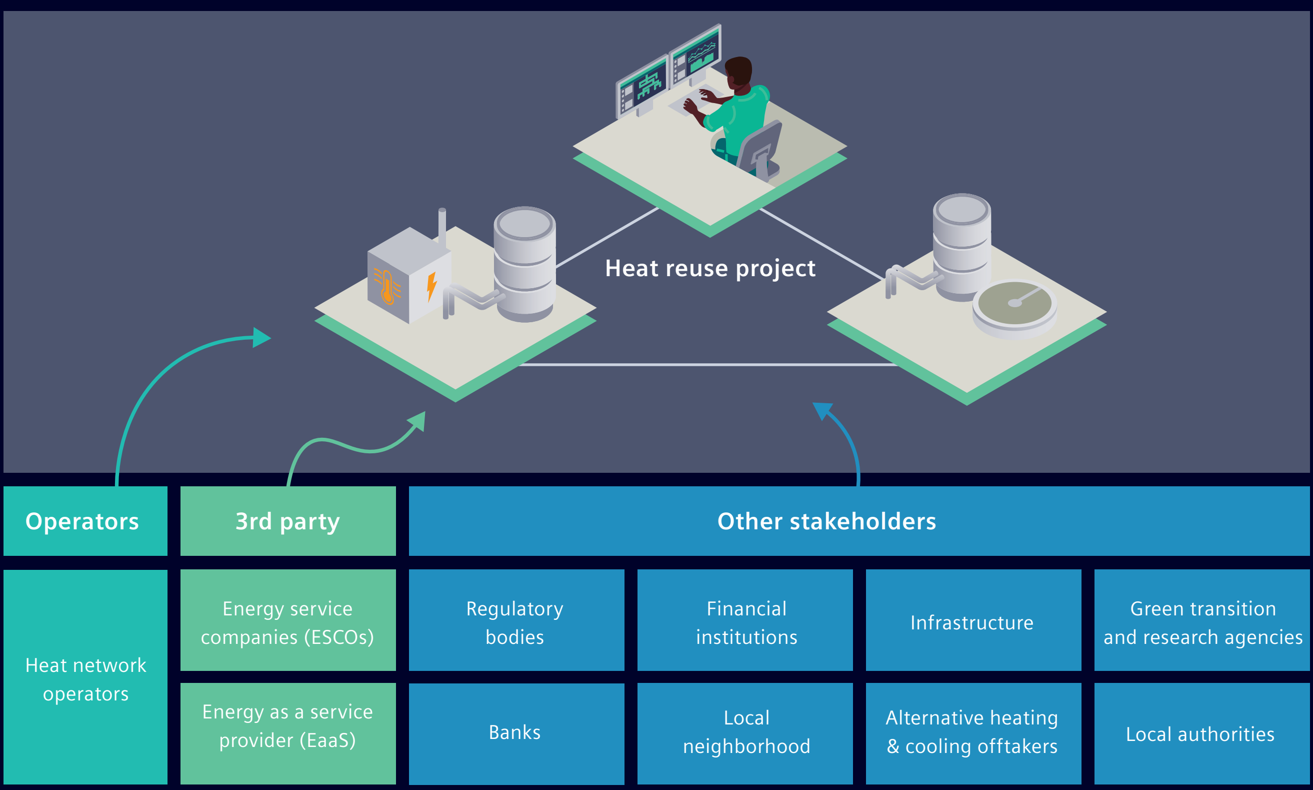
Data center operators are not accustomed to providing long-term services to the local, often tightly regulated DHN market, and expanding their business in this direction may require a significant change in their mindset.

However, heat network operators have the technical expertise, a commercial incentive, and the infrastructure to help achieve targets for renewable waste heat.

There is an active and growing market of third-party specialists providing energy-related services, known as energy service companies (ESCOs), energy performance companies (EPCs), and energy as a service (EaaS) providers. They offer expertise, funding and/or operation of energy-related assets.

Other stakeholders include regulatory bodies, financial institutions, environmental funds, infrastructure funds, green transition and research agencies, local communities, and alternative heating or cooling consumers.

Local authorities have a growing interest in promoting heat reuse in their communities. The variety of stakeholders adds to the complexity of the projects, with each stakeholder having a potential impact on the project's feasibility.



Operational Organization

The normal and most commercially viable model is where the local heat network operator sets up the heat upgrade plant[12], providing cooling to the data center and heating to the district network.

However, for a greenfield project it might be more practical for the data center development team to coordinate the modification of the heat upgrade plant and the connection points in conjunction with their planning and land acquisition. The alternative is for the DHN operator to manage the upgrade and connection as a separate project. Both approaches merit consideration.

Stable waste heat streams are valuable to DHNs, provided they facilitate the generation of high-grade heat at a lower cost than the alternatives. Data center operators also benefit from exporting their waste heat to the DHNs and save on the running cost of their traditional cooling plant.

Heat has most value when the outside temperature is low, but this is when many data centers make use of free cooling, creating a conflict in the supply and demand for waste heat reuse.

To overcome this conflict, it makes sense to encourage data centers to exchange their waste heat for cooling services free of charge instead of utilizing free cooling. This is how Meta manages cooling in Odense[13].

A new heating plant based on heat pump technology is a multi-million-euro investment.

Many heat networks operators may have trouble funding such investments as their budgets may be committed to other business-critical investments.

This provides an opportunity for third-party ESCOs to invest in heat reuse projects, increasing the prospect of these projects happening.

Co-funding between the data center and heat network operator is another option, for example the Open District heating project in Stockholm completed in 2014[14] where a data center operator co-funded a significant share of the heat upgrade plant.

With ambitious targets for 2030 approaching (like the European “Fit for 55” package), funding for decarbonization projects should become more accessible, but securing public funding is often an arduous, time-consuming process.

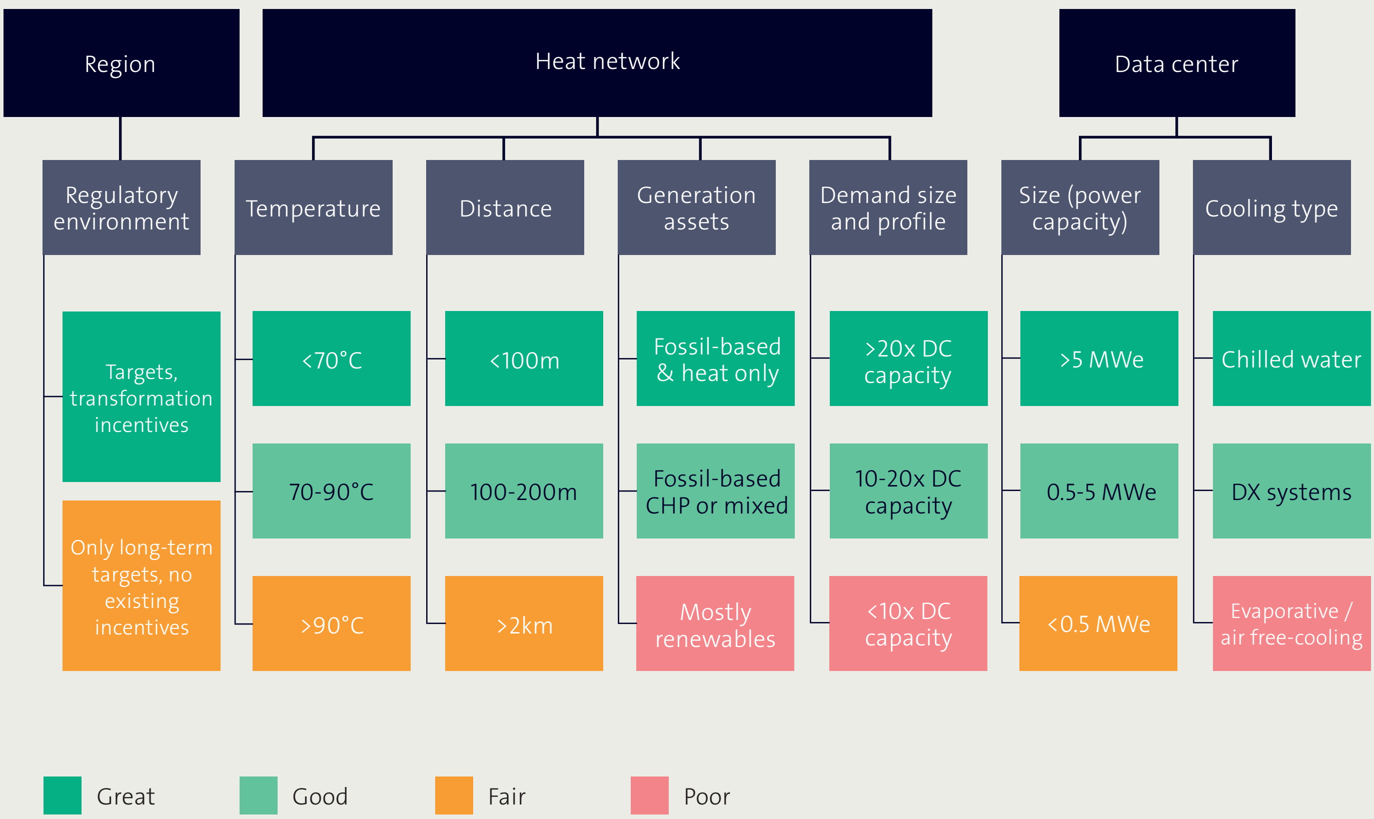
Initial Assessment of Potential Projects

A heat reuse scheme is a significant undertaking with many variables affecting the project's success. For the initial assessment of a location, a conditions assessment chart (see Figure 9) can be used. The parameters to be looked at while undertaking the initial assessment are:

- The overall energy transition investment climate, regulatory challenges, and incentives landscape
- The heat network parameters, such as operating temperatures (seasonality), distance between data center and heat network substation, existing heat supplies, and the size of the heat network relative to the size of the data center.
- The type and size of the data center. These are not critical for the project's feasibility, but they still affect the costs and efficiency, with larger data center designs using chilled water being the easiest to connect to heat networks.

An overview of parameters to be considered in the initial assessment is presented graphically in Figure 9, indicating which conditions are favorable for sector coupling, and to enable prioritization of projects. The parameters have been categorized as "great," "good," "fair" and "poor." The more parameters that fall into the "great" category, the more suitable the project is for connection to the district heating network.

Figure 9 – Overview of assessment criteria and scores



Use Case
10 MW Data Center

Baseline Assumptions

Large data centers continuously generate waste heat, amounting to tens of GWh of heat per annum. Benefits from the efficiencies of scale are important for infrastructure investments, but finding sufficient demand for heat during summertime can be challenging.

This analysis focuses on a 10 MW data center and a mid-size heat network supplying 10,000-20,000 connected households, with an installed heat capacity of 100-200 MW. The ratio of the data center's waste heat and the heat networks requirements is 1:10, allowing 100% of waste heat reuse in the network.

The investment required for 10 MW heat pump installation will depend on several factors, such as a greenfield or brownfield site, available infrastructure, power grid connection, and lengths of pipework. In most European cases, CAPEX is estimated to be somewhere between five and ten million euros.

Some of this investment may be offset when public funding, subsidies, and preferential loans are accounted for. It is estimated that up to 70% of the investment may attract such funding. Data center operators can also benefit from savings on their cooling infrastructure, which needs to adhere to their tier level and redundancy requirements.

Defining the Scenarios

To illustrate the impact of the factors discussed earlier, three integrated cooling and heating options have been examined, with cooling and heating provided separately. The three modes are shown in Figure 5:

- Classic – heating the return water to the feed parameters
- COP efficient – heating the return water by 5°C
- Booster – heating the water slightly below the feed parameters by 5°C

Each model assumes that low-grade heat is provided free of charge to the project and high-grade heat is sold for the price linked to the usefulness of the heat to the system:

- lowest for preheating the return
- mid-level for the classic return to feed upgrade
- highest for high-temperature boosting

The sale may be an external transaction if the project is operated by a third party, or an internal interdepartmental transaction if it is operated by the DHN operator. In practice, heat prices are dynamic and depend on the connection type, outside weather conditions, and other factors. For simplicity, the business cases shown here use averaged values.

Based on the assumed COP and electricity costs of 0.1 €/kWh[15], the cost of heat generation is calculated. The resulting cash flows and the marginal cost of heat generation are used to compare the three models.

Each model uses similar equipment with a cooling capacity of 10 MW and examines the three different connection options presented in Figure 5, which impacts their efficiency (COP). These options are compared to a standalone heat pump solution using surface water from a river or a lake as its heat source. The calculations are based on a full year (8,760 hours) with the same average load.

Results and Discussion

The lowest marginal cost of heat generation, €19/MWh as presented in Table 2, results from the "COP efficient" model and is competitive with natural gas-based heat generation. The "classic" and "booster" models result in heat generation costs of €23 and €30/MWh respectively.

This compares with a heat generation cost of €39/MWh using natural gas, with the gas costing €25/MWh and a carbon cost of €60/tCO_2. This utilization of waste heat saves 20-33% of the cost of heat generation compared to using good quality ambient heat, such as surface water.

In the business case, the difference in cash flow between the "classic" model and a standalone heat pumps results in approximately €0.5M savings per year.

This amounts to 20% of the electrical cost of running a standalone heat pump, effectively reducing the heat generation costs from €30/MWh to €23/MWh. Surprisingly, results show that the most efficient solutions may not be the most beneficial in terms of economic outcomes.

When comparing the various models, the net cash flow for the least efficient model ("booster") is higher than that of the "efficient" model, due to larger amounts and higher value of heat, indicating projects should be looked at from multiple perspectives. This shows the sensitivity of financial results from heat sales prices and generation efficiency (COP).

		Combining cooling and heating			Reference
		Classic	**Efficient**	**Booster**	**Standalone heat pumps**
Temperatures	Cooling/heating	(26-18°C) (60-80°C)	(26-18°C) (60-65°C)	(26-18°C) (77-82°C)	— (60-80°C)
Heat price	€/MWh	€35.0	€28.0	€40.0	€35.0
Electricity price	€/MWh	€100	€100	€100	€100
Cooling capacity	MW	10.0	10.0	10.0	—
COP*	—	4.5	5.5	3.5	3.5
Heating capacity	MW	12.9	12.2	14.0	14.0
Power rating	MW	2.9	2.2	4.0	4.0
Annual heat generation	MWh/a	73,209	69,593	79,716	79,716
Heat revenue	€k/a	€2,562k	€1,949k	€3,189k	€2,790k
Electricity costs	€k/a	€1,709k	€1,329k	€2,393k	€2,393k

Table 2 – Business case scenario assumptions and results
*COP values for chillers only, not for the entire cooling system

At a cost of €6M for the heat pump system, and the availability of an onsite DHN connection, simple payback on the investment is approximately 9 years, without using any subsidies.

This is in line with acceptable investment criteria for these types of infrastructure projects. When we consider the potential subsidies for heat decarbonization projects, the commercial justification becomes more attractive.

The alternative, using ambient heat as a source for heat pumps of the same size, would result in a payback period of more than 30 years.

The values presented are based on average European conditions. There are significant variations across markets in energy, labor, and material prices. Each project is different and needs to be engineered to meet local requirements, such as temperatures, heat demand management and the availability of complementary supplies, etc.

Conclusions

The expertise, economies of scale, and familiarity with regulations place heat network operators in the most favorable position to become the principal project developers for the generation of usable heat from data center waste heat. Experienced third-party ESCOs come a close second, with the potential of being more agile and having stronger financial resources.

Data center operators can promote new projects and offer long-term waste heat supplies to heat network operators or other parties that may be interested in utilizing waste heat, e.g., hospital or university campuses, agriculture or aquaculture, or other potential consumers who may be located a reasonable distance from the data center.

Contractual terms are important to both the data center operator and the DHN. Recent examples show a positive trend where data centers and DHNs have agreed ten-year contracts, subject to certain exit clauses, which deliver predictable economic and sustainable results for both parties.

Data center operators can benefit from:

- Savings in operating costs of cooling systems. For the business case of a 10 MW data center, the savings can exceed €1M annually, depending on the geographical location.
- Further savings in the CAPEX and OPEX of their traditional cooling plants due to the heat network taking the base cooling load and reducing their need for a heat rejection plant.

Heat networks operators can benefit from:

- Operational savings from the increased efficiency of heat pumps. For the business case of a 10 MW data center, the operational savings were approximately €0.5M per annum compared to standalone heat pumps using ambient heat.
- A stable waste heat source which can contribute to their renewable and waste heat reuse obligations.

Reusing heat from data centers is profitable even without subsidies and will always provide a better result than heat pumps using ambient heat. Planned data centers should be, and often are, designed with waste heat export capabilities to enable easy deployment of future connections.

Heat reuse projects can help decarbonize heat networks, but DHN operators might not be aware of the data center potential in their area and prioritize other projects.

Therefore, for projects to materialize, we encourage data center operators to engage early, share information, and actively collaborate with local authorities and heat network operators to influence planning and development of sustainable infrastructure.

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15. Marginal cost being the cost of generating an additional unit of heat above a baseline – it focuses on variable costs of operation.

Table of Abbreviations and Acronyms

CAPEX	Capital Expenditure
CHP	Combined Heat and Power
COP	Coefficient of Performance
CRAC	Computer Room Air Conditioning
CRAH	Computer Room Air Handling
DC	Data Center
DH	District Heating
DHN	District Heating Network
EaaS	Energy as a Service
EPCs	Energy Performance Contractors
ESCOs	Energy Service Companies
EU	European Union
JRC	Joint Research Center
OPEX	Operational Expenditure
PE	Polyethylene
PUE	Power Usage Effectiveness

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