ENGINEERING TOMORROW

Article

Low temperature or ambient temperature district heating?
It all depends ...

Oddgeir Gudmundsson and Jan Eric Thorsen, Danfoss Application Center

Oddgeir Gudmundsson, Director Projects, Danfoss A/S
Jan Eric Thorsen, Director, Danfoss Application Centre, Danfoss A/S

Low temperature or ambient temperature district heating? It all depends ...

With heating and cooling accounting for half of the EU's energy consumption, the energy transition towards more climate-friendly technologies depends to a large degree on decarbonizing heating and cooling supplies. In the quest for energy efficient solutions that integrate renewables and take advantage of synergies between energy sectors, district energy stands out as the most cost-effective and energy efficient pathway to achieve the goals.

Based on the current success of low temperature district heating (LTDH), often referred to as 4th generation district heating (4GDH) systems, the sector has shown that it can be a key enabler in future renewable energy systems. To continue its relevance, the sector is actively researching the future role and potential of district energy in energy systems. One of the most important questions is how district energy can support the next step in improving energy efficiency, flexibility, resilience and cost-effectiveness of the energy systems. At the same time, the increasing availability of renewable and local power sources has made the interaction between the heating and power sectors an active field of research.

One of the research themes is concerned with ambient temperature district heating (ATDH) systems, commonly referred to as 5GDH. In the ATDH systems, the system temperatures are kept as close to the ambient temperature as possible to minimize heat loss. The drawback of these systems is, however, that they require an individual heat pump in each building to boost the supply temperature to the requirements of the building installations. This tends to make ATDH more costly, more complex, less flexible and less resilient than LTDH systems.

The purpose of the study summarized in this paper is to explore how the current best technology, LTDH, compares with ATDH. District energy systems range from small to large, from simple to complex, and a lot of parameters have to be taken into account, before determining the most effective solution, including local building standards, access to different heat sources and combinations of these, local energy tariffs, national subsidy schemes, climate conditions, etc.

For the locations investigated, i.e. Denmark and the UK, the study reveals that LTDH remains the most attractive solution in the light of the costs of establishing and operating the system. The study concludes that LTDH is not only more cost-effective compared to ATDH, it also performs better when it comes to security, reliability, flexibility and resilience.

What is LTDH/4GDH and ATDH/5GDH?

LTDH/4GDH	ATDH/5GDH
• Known as low-temperature district heating, accommodating temperatures from 50-65°C, sufficient to fulfil all heating demands. • Distributed in insulated pipes from any central heat source, including surplus heat from e.g. data centers or industry processes. If the heat source temperature is below system supply temperature, central heat pumps are used to raise the temperature. • All types of heat sources can be utilized.	• Operates at very low temperatures, 10-25°C. • Distributed in uninsulated pipes. • Always requires decentral temperature boost with individual heat pumps to fulfil requirements to space heating and domestic hot water. • Typical heat sources are: sea, lakes, rivers, sewage, mine water, low temperature geothermal energy or waste heat from processes.

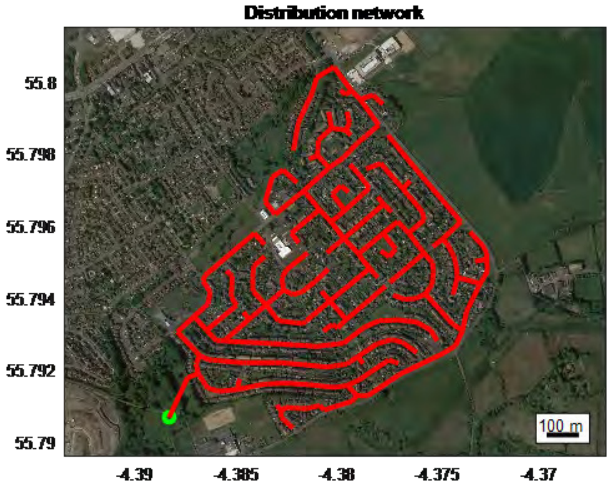

FIGURE 1: The comparison is based on a generic supply area in a green field location, consisting of mainly row houses with 2-6 residential units each, single family villas and some multi-apartment buildings. Two heat demand cases are considered, i.e. low or high energy buildings.

The study also identifies vast differences in the cost of district heating systems in Denmark and the United Kingdom. The main reason is the high cost of establishing the distribution grid in the United Kingdom compared to Denmark. The second reason is the difference in electricity prices between the two countries.

Basic assumptions of the study

To ensure a fair comparison of the different solutions comprised by the study, the systems are compared using the same distribution pipeline layout and heat consumers. The distribution layout is based on a residential area in Northern Europe. For the analyses, the yearly thermal demand for space heating is based on the climate profile of the chosen location. The distribution network is sized based on the building design peak load, adjusted for local heat input and losses from operating the district heating heat interface units, and the defined supply and return temperature for each system type.

The study investigates four different thermal source scenarios ranging from 10°C to 60°C. Depending on the supply system operating temperature, the heat interface units have either heat pumps, heat exchangers or both heat exchanger and a heat pump.

With the chosen system boundary, shown in Figure 2, the study is decoupled from the type of heat source. This is a reasonable simplification as the cost of establishing the heat source will result in negligible differences between the different supply systems. The costs included in the study therefore cover installation, operation and maintenance of a central heat plant, individual heat pump, interface units, distribution network and thermal distribution cost, including thermal losses during distribution.

The study assumes constant temperature levels of the heat source. If the temperature was to vary over the year, it would impact the system in two ways. First, it would affect the COP of the heat pumps in all scenarios; secondly, it would have significant impact on the capacity of the distribution grid in the ATDH systems. It should be noted that the investment and installation costs of technologies can vary significantly between countries. In the absence of country specific cost data, the study uses Eurostat's Purchasing Power Parities to estimate the price differences of components and services, including thermal generation plants and end-user components from one country to another. The price of establishing the distribution pipelines is based on project experience from Ramboll A/S for Denmark and Logstor A/S for the UK. For maximum transparency, the energy prices used in the economic calculations are the country by country energy prices published by Eurostat.

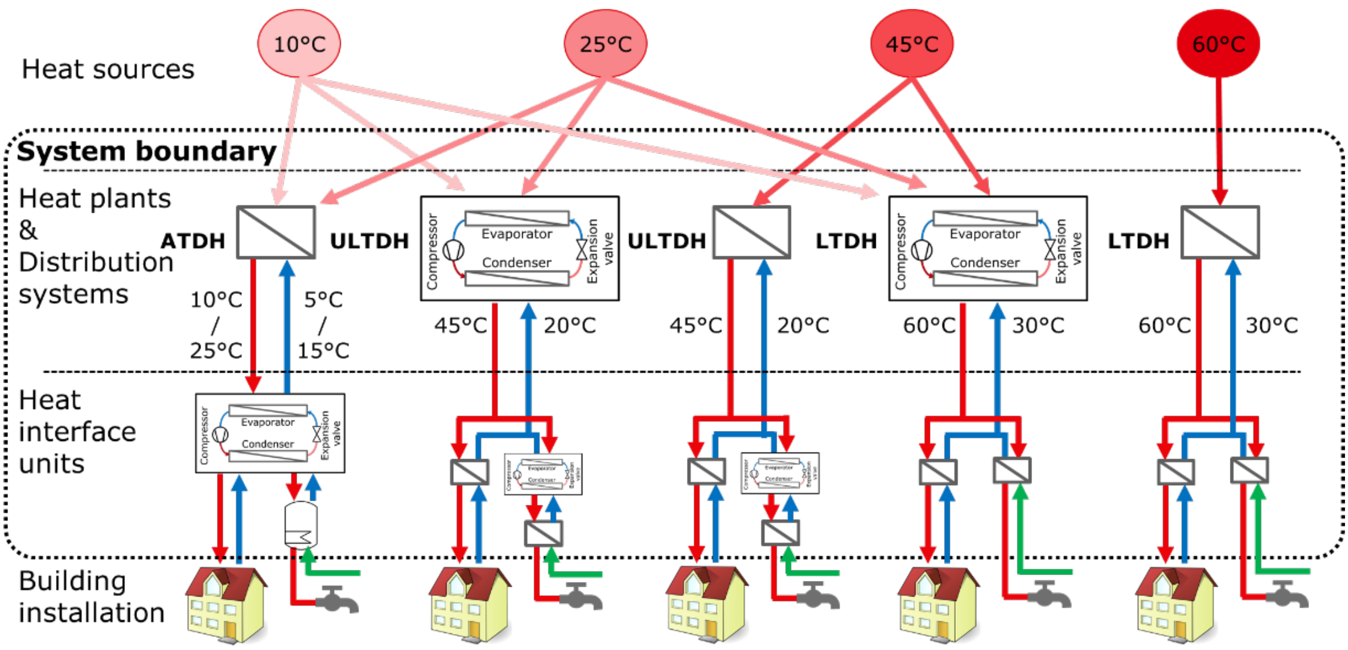

FIGURE 2: TThe figure shows the four heat sources and the resulting five different supply system configurations considered in the study. ATDH (Ambient Temperature District Heating), ULTDH (Ultra Low Temperature District Heating), LTDH (Low Temperature District Heating).

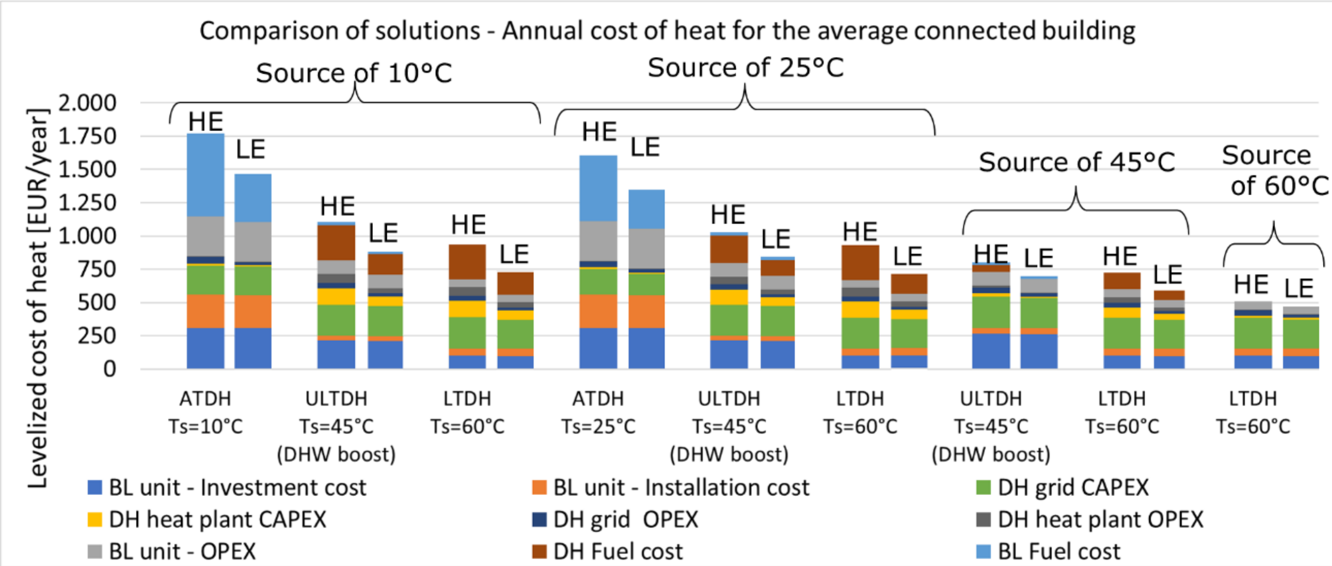

FIGURE 3: The annual levelized cost of heat for the average high energy (HE) and low energy (LE) building in Denmark for different supply systems and thermal source temperatures. Ts is the distribution system supply temperature. The average space heating demand for the high-energy building is estimated to be 15 MWh/year. The average space heating for the low-energy building is estimated at 7.5 MWh/year. Domestic hot water demand is assumed to be 2 MWh/year for both building types.

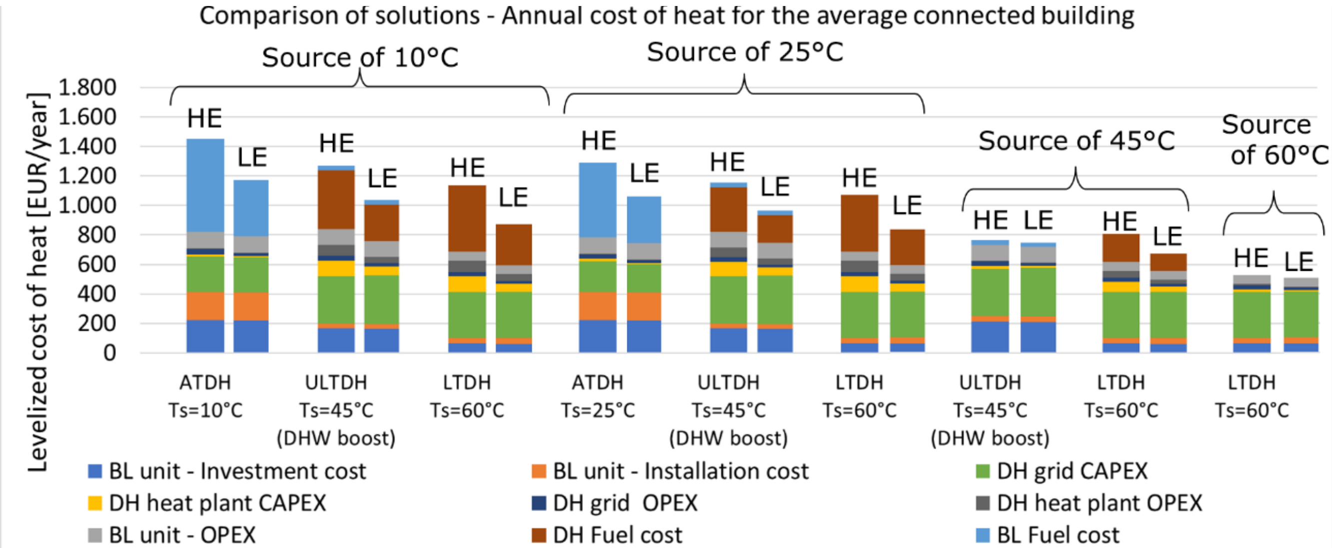

FIGURE 4: The annual levelized cost of heat for the average high energy (HE) and low energy (LE) building in the UK for different supply systems and thermal source temperatures. Ts is the distribution system supply temperature. The average space heating demand for high-energy buildings is estimated to be 11.4 MWh/year. The average space heating demand for the low-energy building is estimated at 5.7 MWh/year. The domestic hot water demand is assumed to be 2 MWh/year for both building types.

Results of the study: Denmark
The results of the study clearly demonstrate that in Denmark, LTDH outperforms ATDH as the most cost effective solution for both high and low energy buildings, independent of the temperature level of the heat source.

The relative cost effectiveness is primarily due to the economy of scale of central heat pumps, simpler building interface units, and the cost of electricity. These factors more than compensate for the additional cost of the insulated pipe network and the distribution heat losses in LTDH systems compared to ATDH.

Results of the study: UK

Although the cost competitiveness of LTDH is less striking in the UK compared to Denmark, the difference still stands out. For high energy buildings, LTDH is 22% and 17% more cost competitive compared to ATDH for source temperatures of 10°C and 25°C respectively. The competitiveness is even higher for low energy buildings, where LTDH is 25% and 21% more cost competitive compared to ATDH for source temperatures of 10°C and 25°C respectively.

The main reason for the differences between the UK compared to Denmark can be ascribed to the applied distribution network practices, where single pipes are the norm in the UK, whereas twin pipes are the norm in Denmark. Experience from Denmark shows that the application of twin pipes instead of single pipes generally leads to 15% savings in establishing the distribution grid. Additionally, twin pipes reduce the distribution heat loss by more than 30%.

Although the general cost of establishing district heating distribution pipelines in the UK has been rapidly decreasing in recent years there is still an unexplained 15% cost difference between equal pipe systems in Denmark. As the market in UK matures that difference is expected to decrease, making the district heating even more cost competitive.

Pros and cons of LTDH and ATDH

While LTDH and ATDH share some of the same system elements, for instance a central heat source and a distribution infrastructure, there is an important difference between the two system types. Where LTDH operates with a centralized thermal plant and insulated pipe network, the ATDH operates with uninsulated pipe network and has consumer located heat pumps. This difference has a major impact on the opportunities for optimizing the system, supply security and thermal resilience of the supply system.

Overview of benefits and limitations of LTDH/4GDH and ATDH/5GDH systems:

LTDH – Benefits and limitations

Benefits	Limitations
• Simple to decouple heat supply and demand by use of centralized thermal storages. • Can take significant advantage of spot market energy prices. • Simple to connect new thermal sources. • Professionally operated thermal generation units. • Simple and robust consumer interfaces. • Cost efficient backup plants. • Low investment in new energy conversion technologies.	• The temperature of low-temperature heat sources needs to be increased to meet the system supply temperature requirement. • Higher thermal loss during distribution, which has to be compensated by more efficient thermal plants or more economic operation. • Cooling services would require a separate cooling module or separate district cooling system. • Supply temperature reduction is limited to the requirements of the critical consumers.

ATDH – Benefits and limitations

Benefits	Limitations
• New ambient temperature thermal sources can easily be connected at low cost. • Negligible thermal loss in distribution. • Distribution pipeline is cheaper due to reduced excavation cost and no pipe insulation. • Potential to switch to cooling by individual consumers.	• No thermal supply in case of power supply failures. • No backup in case of failure of local heat pumps. • Large diameter pipes are needed due to low distribution system temperature difference. • Local maintenance/service on heat pump. • High heat loss if high temperature heat source is connected, because of uninsulated pipes. • Complex and expensive building units. • Technology lock-in, expensive to change.

Let's take a closer look at some of the critical factors that affect the choice of technology and infrastructure for district energy systems in any community.

Flexibility
One of the parameters that sets the LTDH and ATDH solutions apart is the ability of the systems to take maximum advantage of periods with low-cost energy. This flexibility can imply great savings for utilities and end consumers in LTDH systems that operate centralized heat pumps and thermal storage facilities. Centralized heat pumps generally have excess capacity available for most parts of the year which can be used to charge thermal storages during periods of low power costs.
The centralized thermal generation and distribution systems with insulated pipes further enable cost and energy efficient integration of new thermal sources, for example waste heat from processes, supermarkets, datacenters and so forth.

Robustness
When it comes to robustness of the solution, i.e. the ability of the district energy system to supply sufficient space heating during spells of exceptionally cold weather, ATDH may fall short due to flow capacity limitations in the distribution network. LTDH systems would on the other hand be able to ramp up the system supply temperature and effectively increase the capacity of the distribution network.

Reliability
Reliability has to do with the uptime of the system. If a critical component like the heat pump fails, systems with built-in redundancy like LTDH with several central heat pumps and peak load boilers can offer higher reliability than the ATDH solution. The latter relies on domestic heat pumps that in case of failure leave homes without heat supply until it has been repaired or replaced; unless the unit has back-up thermal generation, which is typically not the case due to the high cost of dual units.

Resilience
In general, district energy is considered a resilient energy infrastructure in case of major events like natural disasters, severe weather, cyber-attacks, etc. If the power grid collapses during harsh winter conditions, lack of heat would soon become critical in electricity driven heat generation units. In this case, the centralized LTDH would have the best chance of establishing emergency supplies fast and for all connected consumers. The ATDH systems that rely on building-level power supplies, however, would not be able to operate the heat pump, which would render the system inoperational in case of a power failure.

Switching between heating and cooling
ATDH is often praised for its ability to switch between heating and cooling, which provides improved flexibility and comfort for the individual consumer. While cooling is commonly viewed as a unique benefit of the ATDH systems coming with limited extra cost, it is also emerging as a possibility in LTDH systems as a cost competitive and energy efficient option. In LTDH systems, a small cooling module heat pump would be added to the heat interface unit. In cooling mode, the heat extracted from the home during a cooling phase can either be stored in a domestic hot water tank or sold to the district heating system.

Conclusion
The results of the study clearly demonstrates that in both Denmark and the UK, LTDH outperforms ATDH as the most cost effective solution for both high and low energy buildings. As the sector matures in the UK and moves towards twin pipes, the cost effectiveness of LTDH will further improve compared to ATDH. The high share of electricity in the UK LTDH cost scenario provides opportunities to save costs by taking advantage of central thermal storages and heat generation during periods of low electricity prices. Taking a broader view of the pros and cons of the different system types, the LTDH also outperforms on the 3-R's metrics (Reliability, Robustness, and Resilience). This is most clearly demonstrated in case of a power grid failure that would render the ATDH system non-operational, while the LTDH systems would be able to switch to emergency thermal generation units.

The more centralized the thermal generation is the more flexible the system can be in shifting loads in time and take advantages of low-cost power periods. The centralized thermal generation and insulated distribution system further enables cost and energy efficient introduction of new thermal sources, for example waste heat from processes, supermarkets, datacenters and so forth. However, in the case of ATDH, energy quality reduction is unavoidable if waste heat sources with higher temperatures than the system supply temperature are connected.

More information

Find more information on Danfoss products and applications on our homepage:
www.danfoss.com

Danfoss A/S
Heating Segment • heating.danfoss.com • +45 7488 2222 • E-Mail: heating@danfoss.com