Case studies of existing LTDH systems

There are many examples of district heating systems with low temperature levels around the world. In this section, some of these examples are described, including results in the form of measured data and lessons learned, where available. This is mainly a non-exhaustive literature review, meaning that the selection includes projects that have been studied academically or in other contexts. To find more information or get in contact with contact persons, please refer to the links and references given in each case.

List of case studies

The main data presented is supply and return temperatures (design temperatures and if possible measured values), design temperatures for space heating and DHW, and technologies used to achieve these levels. The available data varies from case to case; a few are merely added for reference and completeness, although little data is available and investigating them further is not within the scope of this report. An overview of the temperature levels of the cases is given in Table 5.

Table 5. Overview of low-temperature DH case studies. Supply, return, DHW and space heating design temperatures in °C. See each case study for measured values and more information. For the spaces which are blank there is currently no available information.

Case study	Country	Supply	Return	DHW	Space heating
Aarhus (Lystrup)	DK	55	30	45	55
Aarhus (Tilst)	DK	55			
Albertslund	DK	35-40	10-15	55-60	35-40
Høje Taastrup (Sønderby)	DK	52-55	27-30	45-50	
Kortrijk (Venning)	BE	50	25	45	
Linköping	SE	60			
Okotoks	CA	37-55		-	
Slough	UK	55	25	43	55
Birmingham (Wednesbury)	UK	55	35	42	55
Stavanger (Østre Hageby)	NO	55-50	30-35		
Västerås	SE	60	25-30		
Ludwigsburg	DE	40	20		
Kassel (Zum Feldlager)	DE	40		-	

Albertslund, Denmark

In Albertslund, a municipality close to Copenhagen, about 2,200 social housing dwellings from the 1960s are being renovated between 2011 and 2015. About 25 % of the area consists of two-storey terraced houses, while the remaining part is one-storey one-family housing units. The houses are renovated to low-energy standard, with solar panels and PV supplying renewable heat and electricity. In order to supply the remaining heat needed for space heating and DHW, the existing district heating pipes are being replaced with a low-temperature district heating system.

Table 6. Key data for the Albertslund case study.

Parameter	Value
Year of construction	2011-2015
New development/renovation	Renovation
Type of houses	Single family houses and apartment blocks
Number of houses	2,200 dwellings
Supply temperature (design)	35-40 °C
Return temperature (design)	10-15 °C
DHW temperature (design)	55-60 °C

Supply-side technologies/System solution/Distribution technologies

- Pulse operation.

Demand-side technologies

- Individual domestic hot water tanks in each dwelling. Since the supply temperature is about 35-40 °C, the temperature is increased to 55-60 °C with a booster heat pump before entering the DHW tank. The heat pump takes heat from the return pipe, cooling it to 10-15 °C. Local solar heating systems are also coupled to the tank, which cover the heating demand for 6 months of the year.
- Direct connection of underfloor space heating systems (designed for supply temperature of 35-40°C and return temperature of 20 °C).

Aarhus (Lystrup), Denmark

Since 2010, a low-temperature district heating system has been in operation in Lystrup, a suburb of Aarhus, Denmark. Lystrup Fjernvarme delivers district heating to a central point at the demonstration. The local site network supplies 40 terraced low-energy houses and one communal building with domestic hot water and space heating

Table 7. Key data for the Aarhus case study. Measured data from 2012.

Parameter	Value
Year of construction	2009-2010
New development/renovation	New development
Type of houses	Terraced houses and one communal building
Number of houses	40 + 1
Total heated area	4,115 m²
Supply temperature (design/measured)	55 / 52.1 °C
Return temperature (design/measured)	30 / 33.7 °C
DHW temperature	45 °C
SH design temperatures (supply/return)	55/25 °C
Trench length	723 m

Table 7. Key data for the Aarhus case study. Measured data from 2012.

Parameter	Value
Supplied heat	282.6 MWh
Delivered heat	232 MWh
Distribution losses	17.9 %

Supply-side technologies/System solution

- Shunt connection to a medium-temperature DH system (supply temperature 80 °C during winter and 60 °C during summer).

Distribution technologies

- All pipes are twin pipes. 82 % are plastic pipes (AluFlex) and the rest are steel pipes.
- Maximum pressure level 10 bar. Minimum pressure difference at substations 0.3 bar.
- Small pipe dimensions were used. Booster pumps raise the pressure locally in the network.

Demand-side technologies

- Two different types of substations are used in this project: substations with 120 litre district heating storage tanks and substations with instantaneous heat exchangers. In both cases the systems are designed for a DHW temperature of 45°C. The risk of Legionella is handled by the small volume approach (reducing the DHW volume to maximum 3 litres according to German guidelines). In the substations with storage, this is achieved by storing DH water and not hot water.
- The heating systems use direct connection; radiators are designed for 55/25/20°C (supply/return/room temperature) and underfloor heating is used in the bathrooms.
- Each dwelling is connected directly to the district heating system (there are no internal systems in the terraced houses).

Lessons learned

This demonstrator project is relatively well studied and described in literature. Some conclusions drawn are [1]:

- The results show that it is possible to supply customers with a supply temperature of approximately 50 °C and satisfy both the storage heater requirements and safe preparation of DHW.
- It is very important to ensure the proper functioning of each substation, otherwise unacceptable return temperatures will result.
- Low network heat loss can be achieved despite low heat demand in the low-energy buildings.
- The distribution heat loss for the area with district heating storage units is slightly lower than in the area with instantaneous heat exchangers. However, this is counteracted by heat losses from the storage tanks, leading to larger total losses in the case with DH storage.
- Despite higher heat losses, the DH storage solution offers some advantages, due to lower peak pressure/load requirements.

Slough, UK

A small, experimental low-temperature district heating system has been in operation since 2010 in Slough, west of London. It consists of an energy centre that supplies heat to nearby dwellings (in total 10 dwellings with 25 residents) and an information centre. The system is intended to demonstrate different renewable technologies in combination with low-energy houses.

Table 8. Key data for the Slough case study. Measured data from 2011-2012.

Parameter	Value
Year of construction	2010
Total heated area	845 m²
Supply temperature (design/measured)	55 / 51.3 °C
Return temperature design/measured)	25 / 35.2 °C
DHW temperature	43 °C
SH design temperatures (supply/return)	55 / 35 °C
Supplied heat	49.6 MWh
Delivered heat	35.7 MWh
Distribution losses	0,28
Trench length	165

Supply-side technologies/System solution

- Small, single-temperature grid
- Biomass boiler
- Ground-source heat pump
- Air-source heat pump
- Solar thermal panels

Distribution technologies

- Twin pipes; steel twin pipes for main pipes and AluFlex for service pipes.

Demand-side technologies

- Direct connection of space heating systems.
- Radiators and forced-air heating.
- Instantaneous preparation of domestic hot water (designed for 10/43°C DHW temperatures and 55/20°C district heating temperatures).
- Each dwelling is connected directly to the district heating system (no internal systems in the terraced houses).

Lessons learned

Some lessons learned from this project are:

- Reported measured values from a period from March 2011 to April 2012 showed some deviations from design parameters, but overall the system was reported to function well.
- The supply temperature was slightly lower than 55 °C, but it was concluded that 50-55 °C was sufficient to satisfy the heat demands of the dwellings.

- The return temperature was higher than expected, with monthly average values up to 42 °C in the first months of the period, but it was lowered to a minimum monthly average of 28°C after a number of corrective measures were carried out: the DHW temperature setting was lowered, water flow through radiators was restricted and the heat exchanger area of heater batteries was increased. Malfunctions and suboptimal settings in substations were also later discovered. It was concluded that the return temperature was sensitive to these kinds of errors, especially in such a small system.

Birmingham (Wednesbury), UK

A small, experimental, actively managed low-temperature district heating system has been in operation since 2015 in Wednesbury, north west of Birmingham. It consists of an energy centre that supplies heat to nearby dwellings (in total 24 dwellings with 24 residents) and a laundry.

Sharing larger, lower cost, lower carbon heat sources using a heat network is a sound concept. Modern, low temperature, 4G heat networks offer exemplary technical performance but fall short of the scalable commercial solution required for them to become the de facto heating solution in the UK. To become the de facto residential heating solution heat networks need to meet the following brief:

"Heat networks must be available to buy as a standardised package that can be specified, installed, and operated as easily as individual gas boilers. They must deliver reduced lifecycle costs without compromising on technical performance or the consumer experience. They must achieve all this at a scale to suit new build developers and social landlords: 20-250 homes."

This project sought to dispel the myths used to excuse over-size and over-temperature heat network designs and show how applying smarter control technology to heat networks can make them more competitive than individual gas boilers, even for small 20-250 home scale suburban developments.

Table 8. Key data for the Wednesbury case study.

Parameter	Value
Year of construction	2015
Total heated area	1500 m²
Supply temperature (design/measured)	55 / 50-60 °C
Return temperature design/measured)	35 / 25-35 °C
DHW temperature	42 °C
SH design temperatures (supply/return)	55 / 35 °C
Supplied heat	x MWh
Delivered heat	x MWh
Distribution losses	x
Trench length	x

Supply-side technologies/System solution

- Small, single-temperature grid
- Gas boiler
- Air-source heat pump

Distribution technologies

- Twin pipes; PEX-a with PUR (Rehau Rauthermex)
- Active management of supply and demand to mitigate distribution constrains in real time

Demand-side technologies

- Intelligent substations and thermostats in every flat networked back to energy cetnre
- Instantaneous DHW preparation. Small volume approach: the hot water volume is less than 3 litres in order to avoid Legionella. (designed for 10/42°C DHW temperatures and 55/25°C (standard draw off) 55/35°C (peak draw off) district heating temperatures).
- Directly connected radiators for space heating (55/35°C at design condition)

Lessons learned

Some lessons learned from this project are:

Smart Heat Networks

A purpose-developed control platform was developed and applied, from utility supplies through to individual radiators, to a heat network that was downsized to the extent that it relied on this system to avoid hitting capacity constraints. This worked as expected.

- Smart networks allow up to 50% reduction in installed capacity vs. passive networks

The same platform was also used to partially automate commissioning (full automation was prevented by hardware limitations), provide technical service level monitoring, and provide integrated retail utility metering/billing/payment collection and account management at minimal extra cost. This level of integration from utility supplies through to individual radiators, including all user interfaces and retail back office capabilities, and all based on internet is believed to be a world first for heat networks.

- Smart networks can substantially reduce operating overheads and the expertise required to deploy and operate heat networks; especially for small scale developments

Heat Density

Heat networks are traditionally seen as a solution for large developments in urban areas with a high heat density. This project has shown that heat networks done well - preliminary figures show distribution losses of the order just 300-350 kWh per year per home - can be attractive for suburban areas (59% of UK housing stock and more than 59% of heat demand); for developments less than 250 homes (the bulk of projects); even where heat density is low (new build and refurbished homes); and compare favourably against individual gas boilers on both lifecycle carbon and cost.

- The addressable market for heat networks could be larger than previously anticipated

A low temperature heat network (55°C flow temperature) was retrofitted into existing buildings of low thermal performance (pre 2002 Building Regulations) and operated with DHW delivered at 42°C. Fundamentally this works, though further work is needed on transient space heating response in order to satisfy UK consumer expectations.

- Low temperature heat networks are viable for many existing buildings

Sizing

Industry practice results in oversized heat networks that cost more to build and operate less efficiently than they might otherwise. This project has highlighted where to focus and what to do about it:

- Designing for intermittent heating at design condition is suboptimal but encouraged
- BREDEM (SAP) needs modifying to account for time/rate of energy use.
- Designing to accepted standards significanty overestimates hot water load
- A national (UK) standard derived from primary data from a relevant sample of dwellings is needed that clients/consultants accepting design liability can cite.

Quality of Service

By some metrics (e.g. % heat loss) peak efficiency was achieved on the pilot network the day that a filter housing split in the energy centre split and the network went cold. (0% heat loss) Clearly this isn't an acceptable Quality of Service. Keeping all of the network fully hot, including the DHW heat exchanger, all of the time, means zero waiting time for DHW to reach temperature and a home that reheats as quickly as possible. It also minimises heat network efficiency so isn't an acceptable Quality of Service either. Somewhere between this and an energy centre failure is a happy medium.

- Given the influence Quality of Service has on heat network efficiency, an appropriate target should be defined and monitored when evaluating heat network performance.

Høje Taastrup (Sønderby), Denmark

In Høje Taastrup, Denmark, the old district heating system has been replaced in an area with about 75 detached houses in an area called Sønderby. The existing system was only about 15 years old, but had distribution losses at levels of 38-44 %. The new system was connected via a shunt connection to the main network, which has a supply temperature of about 80 °C and a return temperature of about 50 °C.

Table 9. Key data for the Høje Taastrup case study. Measured data from 2012[1].

Parameter	Value
Year of construction	2012
New development/renovation	Renovation
Type of houses	Detached houses, built 1997-1998
Number of houses	75
Total heated area	11,230 m²
Supply temperature (design/measured)	55-52 / 55.0 °C
Return temperature (design/measured)	27-30 / 40.3 °C
DHW temperature	45-50 °C
Trench length	2,743 m
Supplied heat	1,228 MWh
Delivered heat	1,052 MWh
Distribution losses	14.3 %

Supply-side technologies/System solution

- Shunt connection to the main district heating system through a “3-pipe connection shunt arrangement”. This solution allows the return water from the main network to be used as primary water in the low-temperature network, but the main supply water can be mixed in to raise the temperature if necessary. The “main network return water” ranged from 30 to 67 °C (47 °C on average) in 2012-2013, whereas the “main network supply water” ranged from 65 to 107 °C (80 °C on average) [1]. Thanks to this solution, the new system was supplied with return water up to 81% of the time.

Distribution technologies

- Twin pipes. Steel twin pipes for main pipes (insulation class/series 2) and flexible twin Alupex for all house connection pipes (insulation class/series 3).
- Maximum pressure level 10 bar, maximum velocity 2 m/s in order to keep down pipe dimensions. Minimum pressure difference at substations 0.3 bar.

Demand-side technologies

- The substations in each house were replaced with new ones, Danfoss Redan Akvalux II VX.
- Underfloor heating systems, indirect connection.
- Instantaneous preparation of domestic hot water. Small volume approach, where the maximum allowed DHW volume in DHW supply pipes is 3 litres. A few houses have DHW circulation.

Lessons learned

Some lessons learned reported from this project:

- The underfloor space heating systems in the relatively newly built houses were suitable for the low-temperature concept. No modifications were needed except new substations.
- The average return temperature was 40 °C, which was higher than expected. The reason was faulty settings or defective components (valves etc.) in a few consumer substations, which resulted in high bypass flow. Troubleshooting these and other building installations is expected to lower the return temperature.

Aarhus (Tilst), Denmark

In Tilst, a suburb of Aarhus, a street with eight houses has been retrofitted with low-temperature district heating. The focus of this project is on how existing houses can be prepared for low-temperature district heating. For this reason, the existing pipes in this street were replaced with new ones, and the temperature was reduced through the use of a mixing shunt at the connection to the main network.

Table 10. Key data for the Tilst case study from year 2013.

Parameter	Value
Year of construction	2013
New development/renovation	Renovation
Type of houses	Detached houses, built in the 1970s
Number of houses	8
Total heated area	1,049 m²

Table 10. Key data for the Tilst case study from year 2013.	
Parameter	**Value**
Supply temperature (design/measured)	55 / 61-66 °C
SH design temperatures (supply/return)	60 / 30 °C
Trench length	237 m

Supply-side technologies/System solution

- The system is connected to the main district heating system through a mixing shunt.

Distribution technologies

- New network: twin pipes, Isoplus for main pipes (insulation class / series 2) and Logstor Alupex for all house-connection pipes (insulation class / series 3).

Demand-side technologies

- Radiators. According to inspections the radiator system is undersized in several of the houses. Some of the houses use a wood stove to ensure enough heating during cold days [8]
- Original DHW heaters were kept in some houses since the district heating company was not able to convince all of the house owners to replace them. Because of this, the supply temperature could not be lowered below 61 °C.

Lessons learned

Some lessons learned are:

- The potential reduction of the distribution losses with just lowering the temperature from 85 to 60 °C was stated
- Some of the houses are dependent on wood stoves in order to compensate for the undersized radiator system, which is not optimal for a district heating area. By installing extra radiator capacity and/or improving the building envelope (for example replacing / upgrading some windows and doors), the houses can shift to only district heating as heating source. This would make the houses better qualified for low-temperature district heating. However, it was difficult for the heating company to motivate the building owners to make improvements to the building envelope and heating installations, despite subsidy offers.
- The district heating company has realized that it is a long-term project to reduce the supply and return temperatures of the network in an existing area. The house owners need to be willing to make energy efficiency measures on their homes and to replace existing equipment.

Västerås, Sweden

A new area of 130 dwellings is situated in Västerås, Sweden. All houses will have district heating, and their energy demand is low because of energy efficient building techniques. In some of the buildings, some household appliances will be supplied with heat from the district heating, such as white goods and towel warmers.

Table 11. Key data for the Västerås case study.	
Parameter	**Value**
Year of construction	2011-

Table 11. Key data for the Västerås case study.	
Parameter	**Value**
New development/renovation	Renovation
Type of houses	Single family houses and apartment blocks
Number of houses	148
Supply temperature (design)	60 °C
Return temperature (design)	30 °C
Delivered heat	908 MWh
Distribution losses	approx. 20 %

Supply-side technologies/System solution

- The low-temperature district heating network is secondarily connected via a heat exchanger to the main district heating system in Västerås.

Distribution technologies

- The DH is distributed in plastic PEX pipes insulated with EPS foam. These pipes were laid at the same time as the piping for water, sanitation, electricity and broadband, which reduced the total time for laying the pipes by a third.

Demand-side technologies

- Direct connection of space heating systems. Forced-air heating in passive houses, and radiators and underfloor heating in the rest.
- Instantaneous DHW preparation. In the apartment blocks, flat substations have been installed; thus no hot water circulation is necessary.
- In some of the buildings, some household appliances are supplied with heat from the district heating system, such as dishwashers, washing machines and towel warmers, adding 1,000-2,000 kWh/year per dwelling. This increases the heat demand of the district heating network, which makes it more cost-effective. It also decreases primary energy use.

Lessons learned

- The investments costs per metre of pipes are estimated to be about 10 % lower than for conventional systems.
- According to Mälarenergi, three conditions need to be met for district heating supply to low-energy houses:
- Lower distribution losses
- Lower investments
- Increasing the use of heat by replacing electricity with heat.

Stavanger (Østre Hageby), Norway

In Norway, a new passive house project with 66 dwellings, consisting of both apartment blocks and terraced houses, was built between 2012 and 2014. The houses will be provided with space heating and domestic hot water heating from a ground-source heat pump system, distributed by a small-scale district heating network.

Parameter	Value
Year of construction	2012-2014
New development/renovation	New development
Type of houses	Apartment blocks
Number of houses	66 dwellings
Supply temperature (design)	55-50 °C
Return temperature (design)	30-35 °C

Table 12. Key data for the Østre Hageby case study.

Supply-side technologies/System solution

- The system is operated as a stand-alone network.
- Ground-source heat pump system with 200 m vertical boreholes in bedrock will cover most of the annual heating demand.

Demand-side technologies

- Flat substations.
- Instantaneous DHW preparation. Small volume approach: the hot water volume is less than 3 litres in order to avoid Legionella.
- Radiators and underfloor heating.
- Washing machines and dishwashers will be supplied with domestic hot water.

Okotoks, Canada

In Okotoks, Alberta, in Canada, 52 energy-efficient detached houses are supplied with a small low-temperature district heating system. Heat is supplied with 2,293 m² solar collectors located on garage roofs, plus natural gas-fired peak load boilers. Both seasonal storage (boreholes) and short-term storage (water tanks) are used. The system supplies the houses with space heating only; DHW is produced independently with solar collectors with back up gas-fired water heaters. This allows for a very low district heating supply temperature.

Table 13. Measured values from July 2011 to June 2012.

Parameter	Value
Year of construction	2007
New development/renovation	New development
Type of houses	Detached houses
Number of houses	52
Supply temperature (design/measured)	37-55 / 40 °C
Return temperature (measured)	32 °C
Distribution losses	5 %

Supply-side technologies

- Solar collectors
- Natural gas-fired boilers.
- Borehole, seasonal storage
- Short-term storage: water tanks.

Demand-side technologies

- Forced-air heating.
- DHW produced independently with solar collectors and gas-fired water heaters; not connected to the district heating system.

More low-temperature systems

Linköping, Sweden

In Linköping, the energy company Tekniska verken operates three low-temperature networks, and more are being built. The supply temperature is 60 °C. Heat is supplied with steel pipes with more insulation than in standard systems. Costs are reduced through smart planning, for example by laying pipes before foundation work is started. Both indirect and direct connection of space heating systems have been used, but in contrast to several Danish low-temperature systems, Tekniska verken has seen no advantages with direct connection.

Kortrijk (Venning), Belgium

In Venning in the city of Kortrijk, Belgium, a passive house area of 64 single-family houses and four multi-family houses (82 dwellings in total), built in 2010-2014, is supplied with low-temperature district heating. A 1 MW woodchip boiler supplies heat to the system and a water tank is used for short-term storage. The design temperatures are 50/25 °C supply/return (Piers, 2013). Space heating systems are indirectly connected. Domestic hot water is produced at 45 °C using DH storage tanks.

Ludwigsburg, Germany

In Ludwigsburg, Germany, an area with low-energy (passive) houses will be supplied with district heating using a concept called "LowEx" (Schmidt et al., 2014). The system is a subgrid of a main grid, where the return temperature of the main grid is used as the supply temperature in the subgrid, at about 40 °C (return temperature 20 °C). The intention is to match ”exergy demand” and ”exergy supply”. Furthermore, thermal solar energy will be integrated. The plan is to supply the main district heating system with a CHP plant and a geothermal heat pump.

Kassel (Zum Feldlager), Germany

In the housing area "Zum Feldlager" in the city of Kassel, Germany, low-temperature district heating is being investigated. The area consists of 140 new low-energy houses (annual specific heat demand 45 kWh/m²). CHP and a ground-source heat pump are options investigated for supplying heat, together with heat storage. DHW is planned to be supplied with solar thermal systems, backed up by electrical heaters, which enables a very low DH supply temperature of 40°C. For the distribution system, plastic pipes are foreseen, reducing both investments and installation time.