Increasing Efficiency

New Guideline for Low Temperature District Heating

Low temperature district heating systems comply with two main requirements for the future district heating and the whole energy sector: high energy efficiency and high share of renewable energy. A number of demonstration projects have proven that a district heating supply temperature at slightly above 50 °C can meet the end-user's space heating and domestic hot water demands in central-northern European climates, in properly designed and operated district heating networks and in-house installations. Based on the experiences from the demonstration projects a guideline for low temperature district heating has been elaborated.

A project entitled »Full-scale demonstration of low temperature district heating in existing buildings« – financially supported by the Danish Energy Agency in the R&D programme EUDP – demonstrates how low temperature district heating (LTDH) can be implemented and operated in three different housing types. The project results are relevant for most European district heating markets including countries that are in the phase of developing their district heating sector.

The definition of LTDH can vary between countries and has been changing through the years. As an example LTDH in Denmark formerly implied supply temperatures of 70 °C in winter and 60 °C in summer. This project has demonstrated that supply temperatures as low as 50 °C to 55 °C all year are possible, which increases the efficiency of district heating and enables the increased use of non-fossil energy sources. In that respect, LTDH makes district heating an even more relevant alternative compared to other heating sources, including individual heating sources.

Christian Holm Christiansen, Senior Consultant, Danish Technological Institute, Taastrup/Denmark, ***Peter Kaarup Olsen***, Project Manager Cowi A/S, Kongens Lyngby/Denmark, ***Oddgeir Gudmundsson***, Application Specialist Danfoss A/S, District Energy Division, Nordborg/Denmark, ***Morten Hofmeister***, Head of Projects, Grøn Energi, Kolding/Denmark

The objectives of the demonstration projects were to put focus on the benefits of decreasing the supply temperature. The results give awareness to the possibilities of LTDH and should influence the design of new systems including house substations, space heating (SH) and domestic hot water (DHW) systems as well as distribution networks. A guideline is now available on how both existing and new district heating areas can become LTDH-ready, even though LTDH may not be possible immediately.

Three demonstration sites

The guideline is based on the experiences from three different demonstration sites representing different types of houses. At all sites, a central mixing shunt was established in order to reduce the supply temperature and boost pressure to the areas; substations and distribution networks were designed accordingly using state of the art heat exchangers and twin pipes. A comprehensive monitoring programme was set up as well. The three sites were chosen to demonstrate different conditions for the implementation of LTDH (*table 1*).

Sønderby – 15 years old existing detached houses

The Sønderby demonstration site comprises 75 detached brick houses built in the year 1997/98. The living area in each house is between 110 and 212 m² with a total heated gross area of 11,230 m².

Although the existing local and privately owned DH system was only approximately 15 years old, the distribution pipelines – pair of single pipes with plastic media pipes – were in poor conditions. The annual network heat loss accounted for about 38% to 44% of the total heat delivered to the network. Due to the heat losses the heat costs were relatively high. It was decided to renew the existing DH system and transfer ownership of the network to the nearby utility Høje Taastrup Fjernvarme. The newly developed concept for LTDH was seen as the obvious solution from the utility side.

A new LTDH consumer substation was installed in each of the 75 houses with indirect connection via heat exchanger for the space heating system (under-floor heating in all houses) and an instantaneous DHW connection via heat exchanger as well. Twin pipes, series 3, were used for house connections, series 2 for street pipes; the series number (1 to 3) is a designation for the insulation thickness (series 3 has the highest insulation). A special 3-pipe mixing shunt, that enables the use of main network return water for supply was developed and installed at the site.

During the monitoring period the supply temperature was kept at 53 °C to 55 °C. As a result the heat loss in the distribution network in Sønderby decreased from 43% to between 13% and 14% corresponding to a reduction of 69%, which is a slightly better result than expected.

Lystrup – new low energy houses

The Lystrup demonstration site comprises 40 terraced low-energy houses and a communal building built in 2009/10 by the housing association BF Ringgården. The dwellings living area is 87 m² to 110 m² with a total heated gross area of 4,115 m².

Two types of consumer substations were developed and installed; one type with primary side storage tank, which enables the reduction of design capacity to 3 kW and supply pipe dimensions accordingly, and one type with an heat exchanger designed for DHW capacity of 32 kW.

Site	Sønderby	Lystrup	Tilst
Buildings			
Number	75	40	8
Type	detached	terraced	detached
Year of construction	1997/98	2009/10	1973
Living area (m^2)	110 – 212	87 – 110	108 – 178
Space heating system	under-floor	radiators	radiators
– design temperatures (°C)	–	55/25/20	individual
Main (street) pipes			
– dimensions (mm – mm/mm)	20 – 20/125 to 76 – 76/250	20 – 20/110 to 60 – 60/225	33 – 33/160 to 48 – 48/180
– insulation class	series 2	series 2	series 2
– trench length (m)	1,433	–	110
House connection pipes			
– dimensions, mm – mm/mm	20 – 20/125	14 – 14/110 to 26 – 26/125	20 – 20/125
– insulation class	series 3	series 2	series 3
– trench length (m)	1,310	–	120
Total trench length (m)	2,740	723	230
Shunt design			
Type	3-pipe (return water)	traditional	traditional

Table 1. Characteristics of the three demonstration sites and systems

DHW distribution pipes and the floor plan of the dwellings were designed in a way that there is a separate pipe supplying each DHW fixture in order to minimize waiting time and avoid DHW circulation. Radiators were design for supply/return/room temperatures of 55/25/20 °C. Twin pipes series 2 were used for all network pipes instead of single pipe pairs, series 1, as planned in the first proposals for the area.

During the first two years of operation, the system was comprehensively monitored. The supply temperature on the LTDH side of the mixing shunt was kept in average around 52 °C, which for these houses resulted in a reduction of heat loss of almost 75% compared to the calculated heat loss with the traditional design with supply temperatures of 80/40 °C that was originally planned at the site.

Tilst – 40 years old detached houses

The demonstration site comprises a street in Skjoldhøjparken with eight privately owned houses with radiator space heating systems. The dwellings living area is between 108 m^2 and 178 m^2 with a total heated gross area of 1,049 m^2. The houses were built at the beginning of the 1970s and the building design is representative for about 40% of the Danish building stock of detached houses. Originally the houses were supplied with heat from individual oil-fired boilers but in 1983 they were connected to the district heating network of the utility Affald Varme Aarhus.

Despite great effort and funding opportunities from the district heating utility, it was not possible to convince all house owners to exchange their water heaters for more efficient units designed for a supply temperature of 55 °C, as originally planned. Although not all consumers changed their water heaters the utility managed to reach a supply temperature of 61 °C during summer and increased the temperature incrementally to 66 °C during the heating season without complaints from the consumers. In relation to space heating, the supply temperature was reduced much more than expected in the planning phase.

Monitoring on the old network started in 2011. In spring 2013, the new network was laid down consisting of twin pipes, series 3 for house connections and series 2 for street pipes. Due to the short monitoring period with the new network, the data was used to generate an energy signature[1)] and based on that, the energy characteristics were calculated for a reference year.

The results of the demonstration indicate that the heat loss saving potential in networks for this type of houses are in the range of 15% to 20% when reducing the supply temperature from 80 °C to 65 °C. Combined with the replacement of the old network, the distribution heat losses were reduced by more than 70% which is in line with the results from Sønderby and Lystrup.

1) A formula giving the heat load as a function of outdoor temperatures. With an energy signature the annual heat load of buildings for a whole year can be calculated based on a limited number of measuring data.

Guideline to LTDH – new and existing, small and large DH systems

With offset in the experiences and results from the demonstration and previous development projects a guideline for LTDH was developed with sections focusing on the different parts of the design and implementation of a district heating system, (*figure 1*). LTDH can be supplied to both new and existing buildings. Thus LTDH systems can be established in new and existing district heating areas. Further, by sectioning the district heating network LTDH can be introduced area by area. *Figure 2* shows four different applications of LTDH:

- connecting a new development area to an existing district heating system,
- establishing a small-scale stand-alone district heating system in a new development area,
- connecting an existing area e.g. by replacing gas boilers with district heating,
- renovation of an existing district heating system e.g. as part of a general strategy to reduce supply temperature.

A LTDH network may be a pre-requisite for connecting new areas – which may have a low heat density – without compromising the comfort of consumers in the existing network. In the demonstration project in Sønderby, return water from a neighbouring area was used as supply in the LTDH area. This was possible because of the less efficient installations in the neighbouring area. Although this advantage may vanish in case the housing instal-

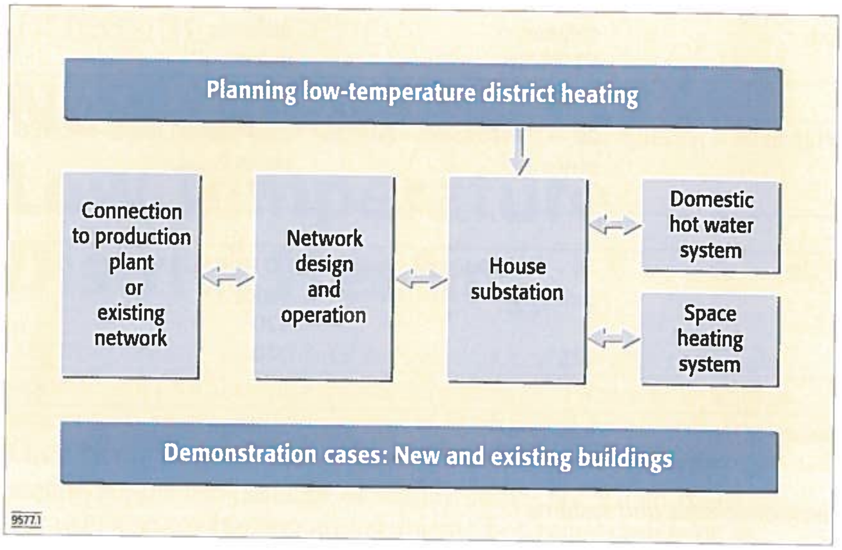

Figure 1. LTDH project guideline process

lations of the neighbouring area are improved, it demonstrates the dynamics and possible synergies in a district heating system, when it comes to cascaded use of the available heat. The design process for the LTDH network is the following:

- Heat demand is defined at consumer nodes with respect to simultaneity factors.
- Network pipes are chosen in a hydraulic optimization. The inputs to the optimization are maximum system pressure, pipe and pump data.

Different LTDH consumer substation units have different peak demands and thus requirements for design load, which allow different dimensions for pipes in the network and especially house-connection pipes. In Lystrup, 11 district heating storage units (DHSU) and 29 instantaneous heat exchanger units (IHEU) were installed for comparison of peak demands. The layout of the DHW distribution pipes should be carefully designed so that there is a separate pipe supplying each DHW fixture and the length and size of the pipes are minimized.

In order to ensure high efficiency in the DH system, it is recommended with a DH pipe design that include:

- Small media pipe dimensions,
- larger insulation thickness,
- PUR-foam heat conductivity,
- diffusion cell gas barrier at the outer casing pipe (keeps the properties of the PUR-foam),
- twin pipes (supply and return pipes in one pipe casing).

Two types of twin pipes can be used – flexible pipes with dimensions DN 14 to DN 32 and (bonded) straight steel pipes with dimensions up to DN 200. Larger pipe dimensions will be in single pipes. Today, pipes with PUR-foam heat conductivity (λ) in the range 0.022 to 0.023 W/(m · K) are commercially available.

From a network point of view there is no superior substation concept, but the best system should be chosen taking into account the specific characteristics of the site, of the demand and consumers comfort requirements. The distribution heat loss in the DH area with DHSU might be slightly lower than in the area with IHEU. However, when the sum of the distribution heat loss and the heat loss from the substations was compared the results showed a marginally higher total heat loss in the DHSU case than in case with IHEU: the additional heat loss due to the storage tanks more than counteracts the reduction of the distribution heat loss. On the other hand, in areas with hydraulic limitations, such as outer urban areas, DHSU offer in return some advantages due to the lower peak pressure/load requirements.

The LTDH concept is specifying normal operational supply temperatures in the range from 50 °C to 55 °C and up to 60 °C to 70 °C e.g. during peak load periods. The lower supply temperatures are pushing equipment and installation specifications to the limits, but can be a new standard for supplying district heating to new buildings. As mentioned, higher supply temperatures might be more suitable for areas with existing buildings and may therefore be adapted to local or national conditions. Most important is that lowering supply temperatures generally is a long term effort and should be prepared well in advance. As house substations, domestic hot water and space heating installations have a technical lifetime of at least 20 years, a starting point could be setting stricter requirements for substations and installations already today in order to harvest the benefits of LTDH as soon as possible.

Conclusions – LTDH is viable

The full scale demonstrations of the LTDH concept have been successful and showed the way for designing DH systems today and in the future. The demonstration projects have gained important experiences and they have shown that the LTDH concept works both for new and existing buildings. It is sufficient to supply district heating consumers with a temperature of approximately 52 °C, which satisfy both the space heating requirements and the safe provision of DHW. If higher temperatures are required during peak load periods the supply temperature could be raised to 65 °C or even higher.

The results of the LTDH demonstration projects show that it is possible to guarantee an energy-efficient operation. But it is very important to obtain the proper functioning in each substation, otherwise unacceptable return temperatures can be expected, which leads to increased heat losses and insufficient utilization of the DH network capacity.

Innovative solutions

Suppliers of equipment have played an active role in the project, focusing on development of new equipment suitable for low temperature district heating.

Substations

A new consumer substation has been developed by Danfoss-Redan (participant in the project), which can operate at supply temperature of 52 °C. District heating companies are adjusting their technical conditions for connection. One of the participating

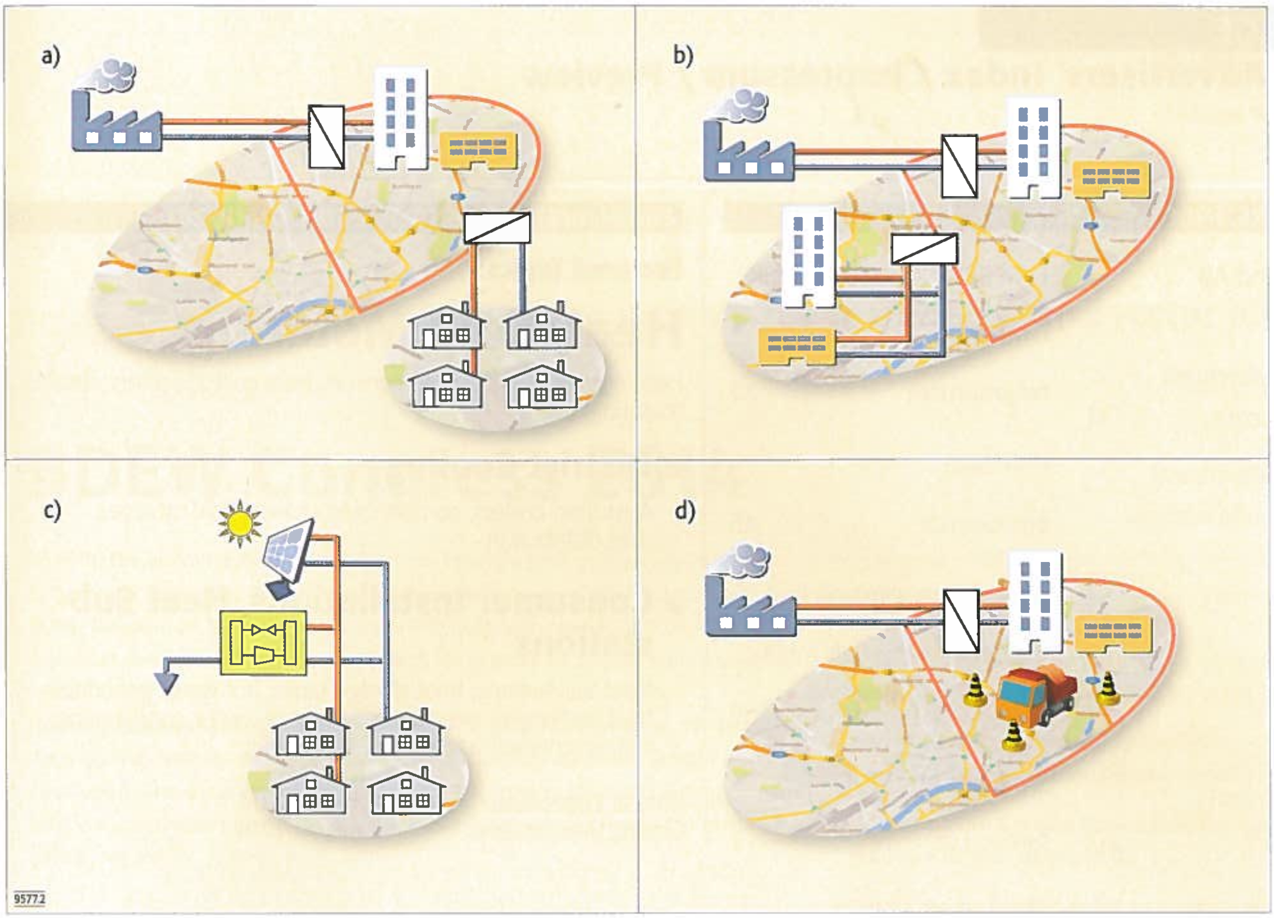

Figure 2. Examples of application of LTDH:
a) Connecting new development areas
b) Connecting existing areas
c) Small-scale district heating for new development area
d) Renovation of existing district heating system

district heating companies changed their dimensioning requirements for consumer substations: today all new substations installed in the network are required to operate with supply temperature of 55 °C. Another district heating company, not participating in the project, has recently adjusted the demand for supply temperature to 52 °C. This is one of the most important results of the project: by setting ambitious standards for the supply temperature, the district heating companies not only increase their competitiveness through higher cooling of the supply but also make their district heating network future proof.

Pre-insulated pipes
The project has demonstrated that pre-insulated twin pipes with high insulation properties and diffusion barrier have a significant influence on the reduction of heat losses. Consequently, the application of these types of pipes is now more commonly applied. Series 3 twin pipes were used for house-connection. Despite the large outer casing diameter, installation went smooth.

3-pipe mixing shunt
In the project, the 3-pipe connection shunt arrangement with an extra connection to the return pipe in the main network was demonstrated. The arrangement makes it possible to utilize up to 100% of the return water from the main network. When the return water temperature is not sufficient for the LTDH network supply, it can be topped with hot water from the supply pipe. In this case the LTDH network is supplied by water mixed from both the supply pipe and the return pipe of the main district heating network.

Implementation aspects

An observation from the project is the influence of utilities organizations. New projects, such as low temperature district heating, imply that current framework conditions may be challenged. A high priority to avoiding complaints from customers must be respected, but might also be a barrier in challenging the »business as usual« operation. The demonstration project in Tilst showed that it was actually possible to reduce supply temperature much more than expected by the utility at the beginning.

The demonstration projects have included changes of the installations in the houses, involving the inhabitants. Some effort has been put in informing the inhabitants throughout the demonstrations to explain the overall benefits of reducing the supply temperature. In the end, the demonstration projects have shown a very large degree of acceptance of LTDH among customers.

Guideline available

The »Guidelines for Low-Temperature District Heating« are available online at fvu-center.dk. ■

cnc@teknologisk.dk
pko@cowi.dk
og@danfoss.com
mho@danskfjernvarme.dk
fvu-center.dk/lavtemperaturfjernvarme
www.gronenergi.org