EUDP J. NR. 64016-0103

ULTRA LOW TEMPERATURE DISTRICT HEATING IN NEW BUILDINGS

Project responsible:
Sweco Danmark A/S
Project partners:
I/S Norfors
Thermaflex Nordic ApS

Date: 25 April 2019
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Controlled by: Johnny Iversen

thermaflex® NORFORS EUDP Energiteknologisk udvikling og demonstration SWECO

PROJECT OBJECTIVE AND RESULTS

English

The purpose of this demonstration project was to implement, demonstrate and promote an energy efficient Ultra-Low Temperature District Heating (ULTDH) concept for new single-family homes with underfloor heating. The concept allows for low district heating temperatures throughout the year, making it possible to demonstrate the full potential of ULTDH. Furthermore, the project also includes an aspect of optimizing the district heating grid for the low temperatures by including the pipe installation side with a focus on optimizing investment costs.

Despite the challenges of finding a suitable ULTDH unit, substantial delays in the land development, and contractors working with an unfamiliar pipe system, the project has demonstrated technical and economic feasibility and positive future perspectives for low and ultra-low district heating technologies. The project is a stepping stone towards the next generation of District Heating combined with Cooling – where District Heating and Cooling are merged into the same pair of pipes balancing consumers' needs for heating as well as for cooling in a decentralised hydraulic network.

Unfortunately, due to delays in the building process only 21 of the 105 planned ULTDH units were purchased during the project period, and it has not been possible to complete the measurement programme to document the performance of the ULTDH units and grid.

The initial developer (Home Deluxe) of the area Niverød Bakke II (later renamed Teglbakken) went bankrupt in the spring of 2017. Since then, new investors have entered the project, and sections of the area are new being sold developed for other building developers. Originally, Home Deluxe planned on constructing the buildings as well as developing the land.

The status as of March 2019 is that Eurodan, contractor for REKA-group, will be starting up in April 2019, planning on building 82 family houses in four stages; the first two stages in 2019 comprising 38 family houses have been decided – the next two in 2020 are optional.

Danish

Nærværende EUDP-projekt har haft til mål at implementere, demonstrere og fremme et energieffektivt ultra-lavtemperaturfjernvarme (ULTFV) koncept til nye enfamilieboliger med gulvvarme. Konceptet muliggør en lav fremløbstemperatur på fjernvarmen hele året, hvorved det fulde potentiale ved ULTFV kan demonstreres. Yderligere omfatter projektet optimering af ledningsnettet til lavtemperaturdrift ved at inkludere ledningsanlægssiden, herunder med henblik på optimering af netinvestering.

Trods udfordringer med at finde en egnet ULTFV-unit, forsinkelser i byggemodningsprocessen og de entreprenørmæssige udfordringer ved at arbejde med et nyt, ukendt rørsystem, har projektet demonstreret teknisk og økonomisk gennemførlighed og positive fremtidsperspektiver. Projektet kan ses som et skridt mod næste generation af fjernvarme kombineret med køling, hvor fjernvarme og -køling er kombineret i samme rørpar for balancering af kunders behov for varme og køl i et decentraliseret hydraulisk netværk.

Grundet forsinkelser i byggeprocessen blev der gennem projektet kun indkøbt 21 af de i alt 105 planlagte ULTFV-units, og det har desværre ikke været muligt at gennemføre det planlagte måleprogram med henblik på at dokumentere performance for såvel ULTFV-units som -net.

Den oprindelige udvikler (Home Deluxe) af området Niverød Bakke II (senere omdøbt til Teglbakken) gik i foråret 2017 konkurs. Nye investorer kom til, og sektioner af området sælges nu byggemodnet til andre husudviklere. Oprindelig ville Home-Deluxe selv opføre husene også.

Status pr. marts 2019 er, at Eurodan, entreprenør for REKA-gruppen, går i jorden april 2019 med en plan om at opføre 82 boliger i 4 etaper, hvor de første to etaper i 2019 omfattende 38 boliger er besluttet – de sidste to er optioner i 2020.

Project: Ultra-low temperature district heating in new buildings	Date: 25 April 2019
Project number: 30.9202.01	Prepared by: Kasper Qvist, Johnny Iversen
Project manager: Johnny Iversen	Controlled by: Peter Sonne
	Accepted by: Johnny Iversen

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5. Presentation at *"3rd International Conference on Smart Energy Systems and 4th Generation District Heating"* in Copenhagen, 12-13 September 2017.
6. Presentation at *"Clean Cluster"* in Middelfart, 17th May 2018.
7. Article at ing.dk[1] *"Gennembrud: Sweco halverer fjernvarmetemperatur i 105 danske boliger"*.

[1] Online version of Ingeniøren

Abbreviations:

8. DH: District Heating
9. DHW: Domestic Hot Water
10. LTDH: Low Temperature District Heating
11. RE: Renewable Energy
12. ULTDH: Ultra Low Temperature District Heating

1. SUMMARY

This project was carried out between October 2016 and January 2019. It was extended by six months from its original deadline July 2018.

The project builds on the experience gained from several previously completed development and demonstration projects that have focused on the development of ULTDH units and ULTDH in existing single-family homes and housing blocks.

In the initial phase, part of the project was to find a proper demonstration site. Various sites were assessed and the site of Niverød Bakke II (later named Teglbakken) was selected. The new residential area comprises 82 connected family houses and 23 detached family houses.

For various reasons, the previously developed Danfoss ULTDH unit could not be used. Instead, a new combined ventilation and District Heating unit was developed together with the Danish suppliers Nilan and Wavin during the project.

The distribution network in Thermaflex pastic pipes was designed and implemented in 2018.

The construction of houses started in April 2019.

2. INTRODUCTION

2.1. Technical description of concept

This project works with a concept for ultra-low temperature district heating (ULTDH) combined with a small booster heat pump for preparation of domestic hot water (DHW).

The concept allows for supply temperatures that are significantly lower than conventional temperatures for Low Temperature District Heating (LTDH), as the use of a heat pump for heating of DHW decouples temperature requirements for space heating and DHW.

Due to this decoupling, it is possible to use supply heat at temperatures below 45 °C all year round.

ULTDH is therefore technically defined as:

“District heating with a supply temperature typically below 45 °C”

Thus, ULTDH introduces the need to raise the temperature for a share of the district heating water, using a booster unit, in order to produce DHW that meets the requirements in DS439. The supply temperature is sufficient for underfloor space heating.

The table below briefly compares traditional district heating (DH), LTDH and ULTDH.

	DH	LTDH	ULTDH
Typical supply temperature	70 °C – 80 °C	50 °C – 55 °C	< 45 °C
DHW production	Storage tank / heat exchanger	Heat exchanger	Booster
Suitable heat distribution system	Radiator / floor heating	Radiator / floor heating	Floor heating[2]
Coupling of temperature for space heating and DHW	Yes	Yes	No

Table 1: Overview of DH, LTDH and ULTDH

2.2. Background

The increasingly stricter building code in Denmark, utility companies energy saving obligations and the planned expansion of the district heating network have driven the development of LTDH and ULTDH with supply temperatures as low as 35 °C.

[2] If ULTDH is implemented in buildings with radiators, it will be necessary to raise the supply temperature during the winter months.

In addition to lower heat losses from the district heating network compared to traditional DH, the lower system temperatures entail several additional advantages, including:

- More efficient integration with low temperature RE sources such as solar and geothermal heating
- Better utilisation of low temperature excess heat
- Distribution of ULTDH from the return water of existing traditional DH systems, resulting in increased capacity of the existing DH infrastructure
- Higher electrical efficiency at CHP plants and better recovery of residual heat in condensing boilers

In addition to the above mentioned, the ULTDH concept applied in this project contributes with other advantages such as:

- Addressing legionella issue
- Smart grid development support by decoupling heating demand and electricity consumption
- Reduction in pressure losses across the DH system
- No interdependence between supply and DHW temperature

2.3. Objective

The overall objective of this project is to promote the development of ULTDH (as low as 35 °C – 45 °C in supply temperature) as a technology and demonstrate the possibilities, robustness and feasibility of the technology.

The project builds on the following previous and ongoing development and demonstration projects, where a district heating unit has already been developed for production of DHW:

- EUDP 11-1, J. Nr. 64011-0076 – Heat Pumps for Domestic Hot Water Preparation in Connection with Low Temperature District Heating, 2011.
- ENS Demonstrationsprojekt: "Demonstrationsprojekter om varmepumper eller VE-baserede opvarmningsformer", 2013-2015 (Geding ved Aarhus). Demonstration Projects on heat pumps or RE-based heating alternatives.
- EUDP 15-1, J. Nr. 64015-0053-1 Ultra-lavtemperaturfjernvarme i boligblokke (Ultra Low Temperature District Heating in blocks of flats), 2015.

More specifically, this project aims to demonstrate the concept on a larger scale in a new-built area and under optimal design conditions. The concept is therefore implemented in an area of new low-energy buildings with floor heating, making it possible to have a low system temperature throughout the year. This makes it possible to demonstrate and prove the full benefits of ULTDH.

Further, the project aims to demonstrate some of the potentials for optimization of the district heating network itself as a result of the low temperatures of ULTDH.

Presently, construction costs of DH networks often make up most of the economy of district heating when compared to individual alternatives. This is due to high costs for excavation and the piping mainly being carried out with steel pipes requiring manual welding work.

In order to minimize these costs as much as possible and try to reduce construction time, the pipe supplier Thermaflex have been involved in the project as they provide products that are optimal for ULTDH conditions. The low temperatures of ULTDH makes it possible to construct the entire district heating network with plastic pipes. Using plastic pipes is not a new technology, but in collaboration with Thermaflex, this project includes an analysis, development and design phase, intended to develop and demonstrate better processes for construction of ULTDH networks as a tool to reducing the construction costs.

2.4. Project description

The project is divided into two overall phases:

Phase 1: Analysis
Phase 2: Implementation, validation and dissemination

Each phase is divided into several work packages:

Phase 1:

WP 1: Project management
WP 2: Description of problem and purpose, delineation and choice of site

WP 3: System analysis
WP 4: Analysis and development of ULTDH pipes and installation methods
WP 5: Interim evaluation and dissemination

Phase 2:

WP 6: Design, tender and procurement
WP 7: Installation of units and construction of ULTDH network
WP 8: Tariff structure and technical regulations
WP 9: Demonstration by measurement, testing and verification
WP 10: Final evaluation and dissemination

3. PROJECT BOUNDARIES

The technical demonstration of the low temperature concept with an integrated heat pump for DHW is, in principle, independent of how the supply is generated (35-45 °C), so the technical demonstration can be placed in many different system contexts.

As there is a wish to test the concept in connection with new low-energy buildings with floor heating, it is necessary to locate a site for demonstration where this type of buildings is planned and expected to be completed within the timeframe of this project.

The concept is based on direct connection of the district heating unit, so all buildings in the selected area will be required to be connected.

Therefore, the following criteria must be considered prior to the final choice of site:

- Timing of construction and municipal approval hereof.
- Developer's acceptance
- Size and economy of the construction
- Acceptance from the utility company
- Municipal authority approval etc.

According to the initial project schedule, 65 district heating units incl. implementation of these were foreseen. However, due to unforeseen delays in the land development process for the demonstration site, the number of district heating units financed through this project has been reduced to 21. It is expected that the remainder will be realized outside this project.

4. DEMONSTRATRION SITE

4.1. Selection of demonstration site

During the selection of the demonstration site, dialogues have been conducted with relevant stakeholders on the following possible sites:

- Brønsholm Eng, Kokkedal (Norfors)
- Kongevejen, Fredensborg (Norfors)
- Eltang (Kolding Kommune)
- Holbæk/Roskilde (Fors)
- Niverød Bakke II, later named Teglbakken, Nivå (Norfors)

The evaluation favoured the newly developed residential area called Teglbakken in Nivå. The area consists of a total of 105 connection points, of which all will be established with ULTDH supply.

Norfors, the district heating supplier, was very interested in the concept and accepted that the site could be used as a demonstration site.

Teglbakken is a residential area in Nivå consisting of 105 newly built homes.

- 23 detached single-family houses
- 29 one-storey houses
- 38 double houses in two storeys
- 15 two-storey houses

All buildings are constructed according to BR15, and the total heat demand is estimated to approx. 825 MWh/year.

Below is an overview map of Teglbakken.

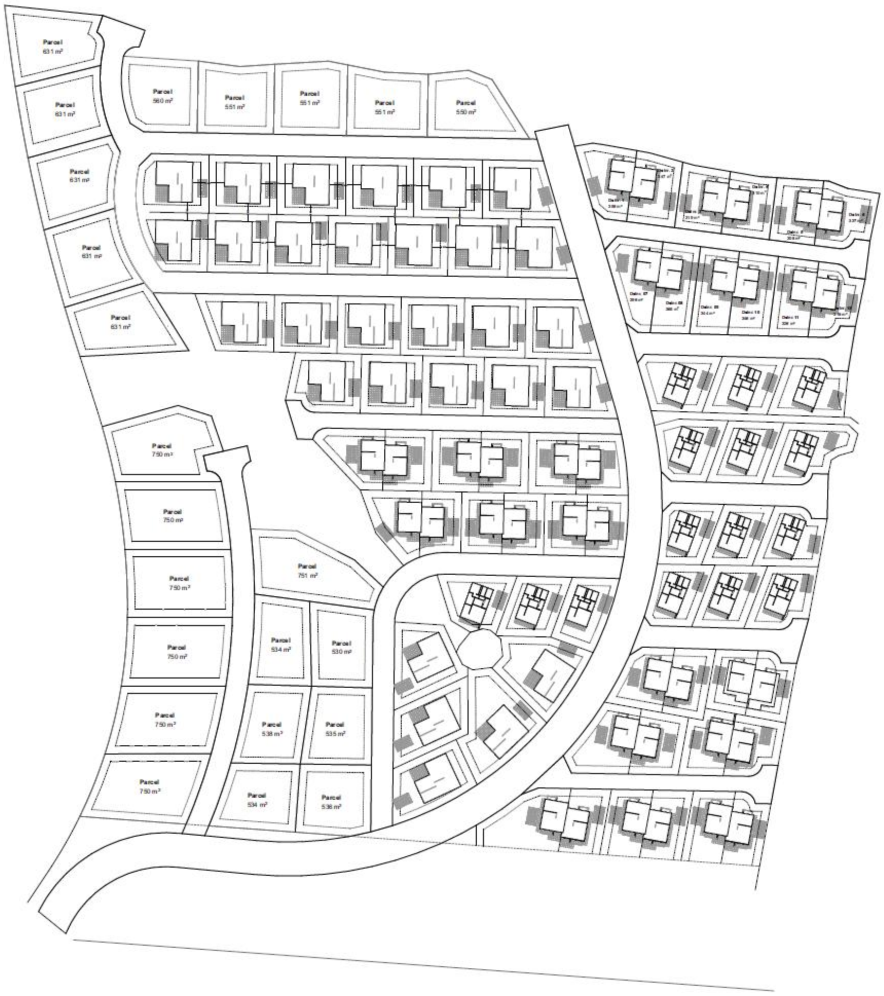

Figure 1: Draft building plan for Teglbakken. Source: Home Deluxe A/S (original developer).

The following figure shows a sketch of the ultra-low temperature district heating grid in Teglbakken including connection points.

Figure 2: Sketch of the ULTDH grid in Teglbakken.

5. DESIGN AND SPECIFICATIONS

5.1. ULTDH Units

Final design, adjustments etc. of the ULTDH units have been made in cooperation with Nilan and Wavin. The final design is based on Nilan's existing Compact S products which are ventilation solutions with heat recovery and a heat pump for production of DHW.

5.1.1. Essential data and specifications

The overall design data and requirements are shown below:

District heating supply temperature	35-60 °C (35-45 °C expected)
District heating differential pressure	min. 0,2 bar
District heating pressure	max. 16 bar
Cold water pressure	max. 10 bar
District heating design supply temperature	45 °C
Charging temperature to tank	58 °C
Design return temperature, district heating	20 °C
DHW temperature @ 22 kW	45 °C (acc. DS 439, 4. edition)
Tank capacity	160 litres
Electricity consumption, heat pump	max. 2,2 kW (230 V, ca. 9,6 amp.)
COP heat pump	Expected: 5-6
Refrigerant	R134a

Measurements of cabinet (LxWxH)	60x60x225 cm
Weight	160 kg

5.1.2. Function and diagram

The concept of this project is based on a DHW production where the district heating preheats the cold water from approx. 10 °C to approx. 40 °C and delivers it to the bottom of the unit's storage tank.

DHW is assumed to be preheated with the district heating temperature delivered through a heat exchanger that heats the bottom of the storage tank.

The preheating is insufficient to produce DHW at a temperature that meets the Danish water standard DS 439, so the built-in heat pump is used to raise the temperature in the tank from 40 °C to the set point (about 55 °C).

The heat pump supplies heat into the top of the storage tank through a spiral exchanger. This prevents the heat pump from heating the district heating return. The heat pump runs until the set point of the storage tank is reached.

A general diagram of the ULTDH unit is shown in the following figure.

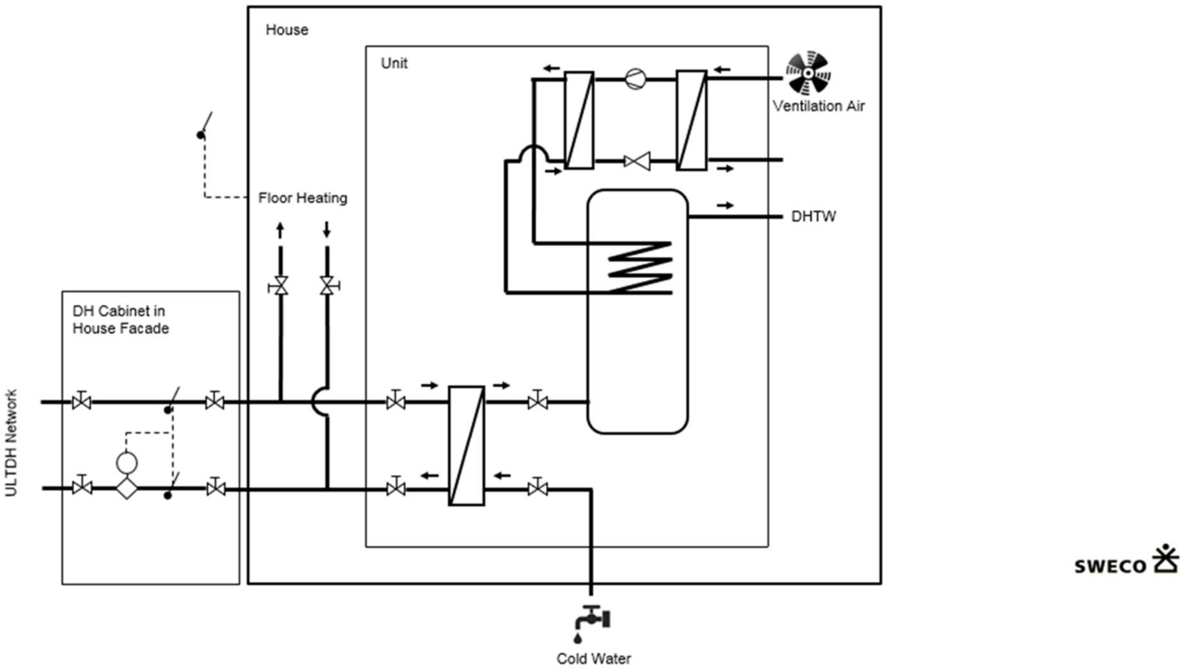

Figure 3: Diagram of the ULTDH concept

The following figure illustrates the ULTDH unit as supplied from Nilan with cabinet. The upper part contains a storage tank and heat pump, while the district heating unit is located at the bottom.

Figure 4: The ULTDH unit as supplied from Nilan with cabinet

5.2. Distribution grid

As part of the project, Thermaflex have been working on optimizing their pipe systems for ULTDH as well as installation methods with a focus on reducing the costs associated with pipe installation.

Specifically, the aim for Thermeflex has been to:

- Optimize pipe design and dimensions for ULTDH
- Analyse and estimate total investment costs for pipe installation
- Investigate and develop new tools and methods for optimizing transport, handling, storage and installation of pipes.

The costs of the distribution grid turned out to be only marginally lower than a traditional steel pipe network. Some logistic problems occurred during the implementation caused by unexperienced handling of this new type of laying method.

6. ORGANIZATION AND CONTRACTUAL RELATIONS

6.1. Special agreement for low temperature district heating

The supply company Norfors purchased the newly developed DH units, which then became an expense for the building owner as part of the connection costs. This arrangement was made because these combined ventilation and DH units could not be purchased on the market as a commercial product.

6.1.1. Ownership

The following points regarding ownership apply to the ULTDH unit:

House owners own all internal installations. Norfors delivers heat at a valve set and measuring point, which is normally located in a built-in cabinet in the facade or in a stand-alone cabinet just outside the facade.

6.1.2. General regulations

Norfors' general regulations have not been changed in connection with this project.

6.1.3. Technical regulations

Because of the changed technical conditions of ULTDH, new area specific technical regulations will be developed resulting in certain technical regulations in *"Nivå Fjernvarmes Tekniske Bestemmelser"* being changed and/or deleted. This includes a dimensioning supply temperature of 70 °C and the requirements for cooling of the district heating water.

6.1.4. District heating tariffs and end-user economy

As part of previous similar projects and this project, a low temperature tariff structure for Norfors has been developed.

Norfors' low temperature tariffs will apply in Teglbakken.

In order to estimate the end-user economy of the ULTDH concept compared to traditional low temperature district heating (LTDH) an example for an average home of 148 m^2 in the area has been calculated in the following.

Reference scenario (LTDH)

Single-family home BR15:

- 148 m^2
- 7,8 MWh/year heating demand
- 50 % used for space heating
- 50 % used for DHW

Everything is calculated incl. VAT.

	Price	Unit	Consumption	Unit
Fixed meter tariff	725,00	kr.	725,00	kr./year
Fixed space tariff	32,50	kr./m^2	4.810,00	kr./year
Variable energy tariff, space heating	993,75	kr./MWh	3.875,63	kr./year
Variable energy tariff, DHW	993,75	kr./MWh	3.875,63	kr./year
Totat heating expense			13.286,26	kr./year

Table 2: Yearly heating expense for an average home in the area under traditional conditions.

ULTDH scenario

The same parameters for an average home in the area apply in this scenario.

50 % of the heating demand, 3,9 MWh/year, is used for space heating and the payment for this is according to the existing tariffs. The remaining 50 % is delivered partly from the district heating grid and partly from the heat pump in the ULTDH unit.

Further, it is assumed that the DHW is preheated from 10 °C to 40 °C by district heating and the remainder from 40 °C to 55 °C is preheated by the heat pump. This corresponds to district heating delivering approximately 2/3 of the heat and the heat pump 1/3.

The average year COP for the heat pump is expected to be approx. 4,0 at a temperature increase of 15 °C.

Based on the above, the heat pump will have to deliver 1,3 MWh of heat amounting to an electricity consumption of 325 kWh/year.

	Price	Unit	Consumption	Unit
Fixed meter tariff	725,00	kr.	725,00	kr./year
Fixed space tariff	32,50	kr./m^2	4.810,00	kr./year
Variable energy tariff, space heating	993,75	kr./MWh	3.875,63	kr./year
Variable energy tariff, DHW	993,75	kr./MWh	2.583,75	kr./year

Electricity cost, heatpump	2000,00	kr./MWh	650,00	kr./year
Totat heating expence			12.644,38	kr./year

Table 3: Yearly heating expense for an average home in the area under traditional conditions.

7. IMPLEMENTATION AND COMMISIONING

7.1. District heating supply

The district heating supply to Teglbakken is taken from Norfors' existing district heating grid in Niverød where the supply temperature is typically approx. 70-80 °C and the return temperature 35-40 °C.

In order to supply Teglbakken with ULTDH with a supply temperature around 45 °C, a minor heat exchanger station is needed between the existing DH grid in Niverød and the new ULTDH grid at Teglbakken. This has been established in the south-eastern part of the new-built area as shown in the figure below.

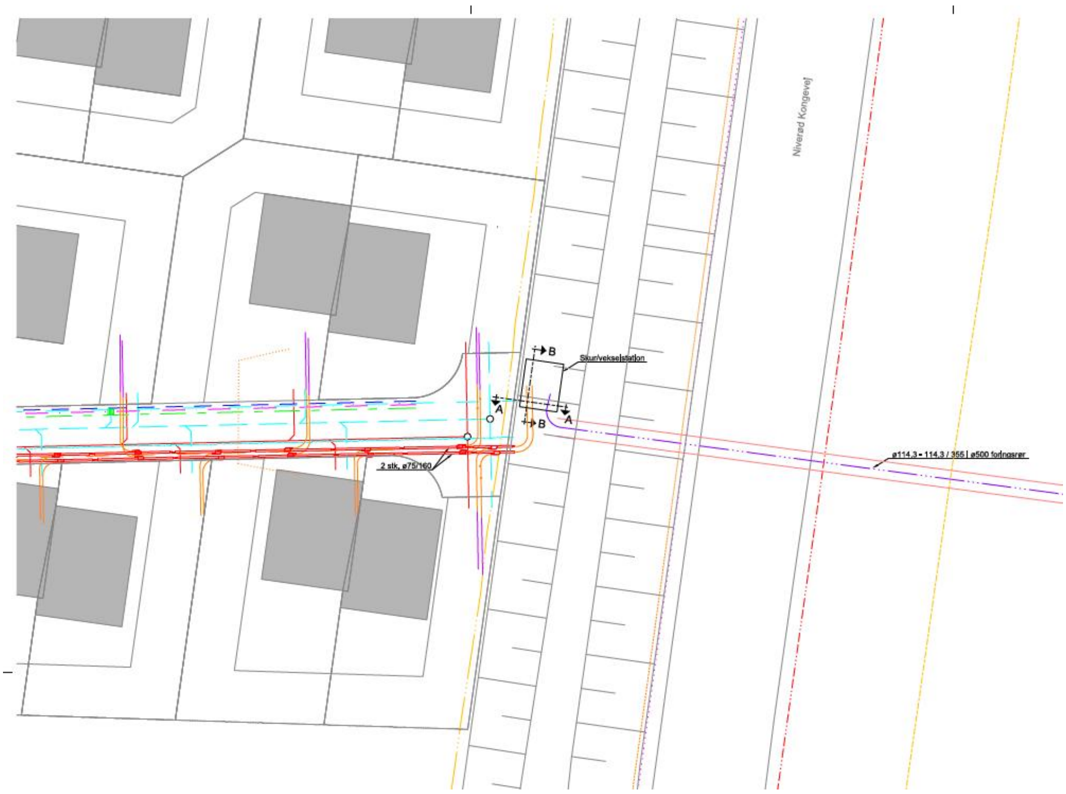

Figure 5: Location of the ULTDH heat exchanger station.

A sketch of the heat exchanger station is show in the following figure.

As shown, the heat exchanger station has the same components as a traditional district heating substation, containing:

- Shut-off valves (both pipes on both primary and secondary side)
- Energy and temperature measurement on the primary side
- Thermometer and manometer (both primary and secondary side)
- Strainers before heat exchanger (both primary and secondary side)
- Control valve with TD regulator on the return pipe on the primary side
- Safety valve on the secondary side
- Temperature transmitter for control of the control valve
- Modulating booster pump
- Surge tank on the return pipe on the secondary side

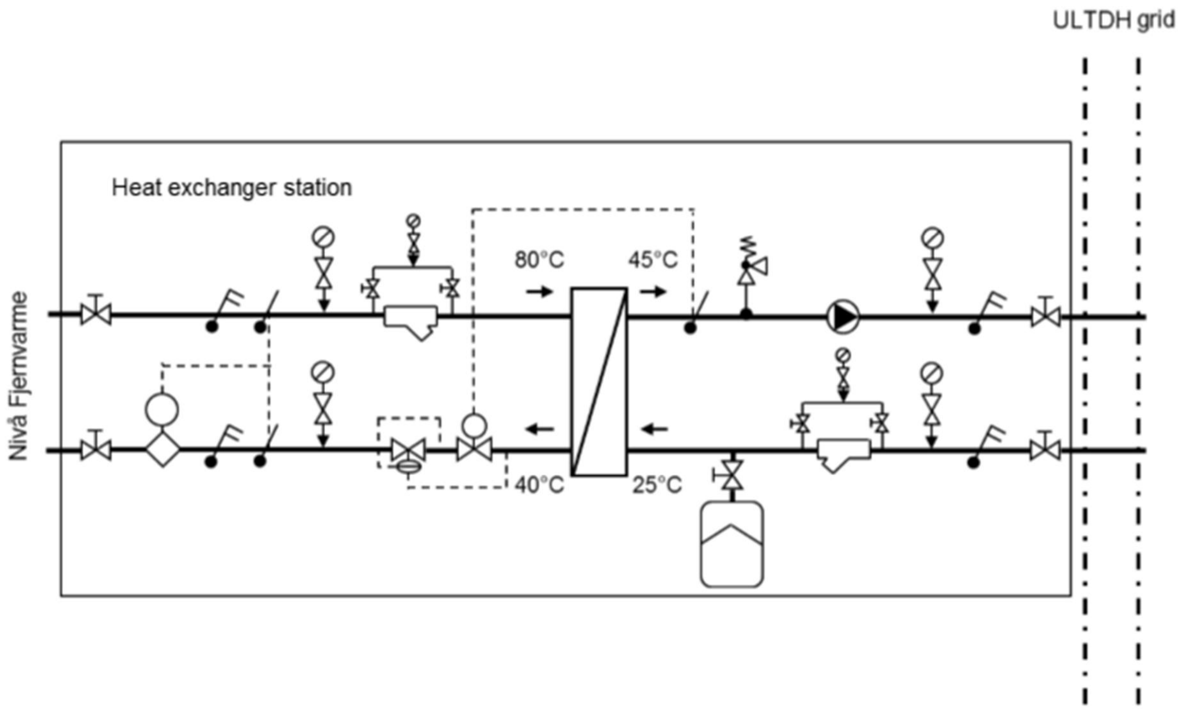

Figure 6: Diagram showing the composition of the heat exchanger station for ULTDH supply.

7.2. Distribution grid

Because of the low system temperatures of ULTDH, it is not necessary to use steel pipes for the distribution grid. Other more flexible materials can be used, with the potential of reducing both material and labour costs.

In this project, a flexible pipe system from Thermaflex was used for the distribution grid. For the main pipes the Flexalen system was used while the Flexalink system was used for service pipes. In total, the district heating network in Teglbakken consists of more than 400 m of pipes.

7.3. ULTDH units

Prior to this project, no commercial solutions for ULTDH units existed. Therefore, several producers of district heating units were contacted in order to develop and deliver a ULTDH unit.

As part of this project a combined ventilation and DH unit was developed with the Danish suppliers Nilan (ventilation) and Wavin (DH unit).

The developed ULTDH units used in this project were supplied by Nilan. The units are based on Nilan’s existing Compact S ventilation solutions with heat recovery and a heat pump for production of DHW as described in section 5.1.

7.4. Experience in connection with implementation

7.4.1. Distribution grid

In relation to the flexible pipe system from Thermaflex used for the distribution grid, the following experience has been gathered during the implementation process:

Pros:

- The pipes are lighter compared to traditional district heating pipes. As a result, they can be handled by hand to a greater extent.
- The pipe material is very flexible, making it possible for the pipes to be bent and rolled out in long lengths. In areas with long sections between service pipes and branches, a roll of pipe can reduce the construction period substantially.

Cons:

- The outer pipe casing is relatively soft and vulnerable to damage.

- It takes some time for the plastic welding to cool.
- The welding machine can only weld one sleeve at a time. It would be an advantage to have the possibility of welding two sleeves at the same time.
- The Flexalen material is very “lively” and has a tendency to twist making it necessary to fixate the pipes in order to avoid unintended bending.
- The DH pipes in twin pipes need to be twisted when valves are installed in the grid. The DH pipes are opposed vertically when laid in the ground but they have to be opposed horizontally when connected to a valve.
- The Flexalen concept still has room for improvement. There have been situations with components that do not seem fully developed yet.
- Flexalink branches seem complicated as many different types were needed in the project.

8. VERIFICATION AND MEASUREMENTS

Early in the project, a verification and measuring programme was outlined.

However, the delayed erection of houses resulted in the verification and measuring programme never being carried out. It is the plan to do some verification and evaluation outside of this project, when a sufficient number of houses have been built.

Besides a substantially lower heat loss, the evaluation will include other system benefits for the supply company, for example:

- Easier integration of RE technologies (solar heat, waste heat, geothermal heat etc.),
- Benefits at the production facilities caused by lower grid temperatures (increased flue gas condensation, increased efficiency of electricity production),
- Increased efficiency of central heat pumps.

8.1. Measurement programme

As part of this project a measurement programme has been developed with the purpose of documenting the technical performance of the ULTDH system, including:

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9. DISSEMINATION

This EUDP project has been presented/disseminated through:

- Leaflet for new consumers at Teglbakken
- Data sheet for new Nilan ULTDH
- Presentation at *“7th International Symposium on Energy”* in Manchester, 13-17th August 2017
- Presentation at *“3rd International Conference on Smart Energy Systems and 4th Generation District Heating”* in Copenhagen, 12-13 September 2017
- Presentation at *“Clean Cluster”* in Middelfart, 17th May 2018
- Article at ing.dk[3] *“Gennembrud: Sweco halverer fjernvarmetemperatur i 105 danske boliger”*

Initially it was expected that the ULTDH grid and units would were designed, implemented and commissioned by the start of the heating season 2017/2018.

However, due to challenges related to the land development and to finding a supplier of ULTDH units, the time schedule was delayed significantly. The ULTDH grid was not completed until the end of 2018 and now houses will be built before the summer of 2019.

[3] Online version of Ingeniøren