

Hovedrapport

Energistyrelsen – EUDP 2013-II

Journalnr. 64013-0554

UDVIKLING OG TEST AF FJERNVARMEUNIT MED ELPATRON TIL ULTRA-LAVTEMPERATUR FJERNVARME

Juli 2016

COWI

Danfoss



DANISH
TECHNOLOGICAL
INSTITUTE


Odder Varmeværk

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The present project "Development of district heating unit with electric booster for ultra-low temperature district heating" is a small scale demonstration project supported by the Danish Energy Agency through the energy development program EUDP 2013-II and is executed with the following project consortium:

- COWI A/S; Niels Vilstrup, Søren K. Christensen
- Teknologisk Institut; Christian H. Christiansen
- Danfoss A/S; Marek Brand, Jan Eric Thorsen
- Odder Varmeværk A.m.b a.; Lars Overgaard Lisberg

This report describes the project objectives, execution and results from the demonstration of the ultra-low temperature district heating system performance. The demonstration took place in Saloparken 301-305, 8300 Odder, which are connected to Odder Varmeværk's district heating distribution network.

The project consortium would like to thank all the residents in Saloparken for their positive contribution to the project. The residents have been cooperative and interested in the project.

Also a special thank you to Odder Varmeværk to make the present demonstration of ultra-low temperature district heating in existing houses possible.

Niels Vilstrup (COWI A/S), Project Manager, July 2016.

1. Project details

Project title	Fjernvarmeunit med elpatron til ultra-lavtemperatur fjernvarme (Development of district heating unit with electric booster for ultra-low temperature district heating)
Project identification (program abbrev. and file)	64013-0554
Name of the programme which has funded the project	EUDP
Project managing company/institution (name and address)	COWI A/S, Parallelvej 2, 2800 Kgs. Lyngby
Project partners	Danfoss A/S, Teknologisk Institut A/S, Odder Varmeværk A.m.b.a
CVR (central business register)	44623528
Date for submission	19 August 2016

GUIDELINES FOR FINAL REPORT

General

*Depending of project type, project size and project complexity the **number of pages** in the final report may vary. For smaller **demonstration** projects the final report normally should not be more than 20 pages plus possible relevant appendices.*

The final report will be used for dissemination purposes and the information given in the final report should be suitable for dissemination, cf. point 4.

2. Short description of project objectives and results

English version

Main objective of the present project is to develop and demonstrate a new concept for the future district heating (DH) networks, which in present project is named 5th generation district heating system. In the present 5th generation- / ultra-low temperature DH system, the supply temperature is 40°C and the return temperature is down to 25-30°C. A prototype DH substation with instantaneous heat exchanger and built-in electric heater for producing domestic hot water (DHW) in the house at a temperature >45°C is developed, tested and demonstrated.

Overall objectives of the project are:

- Development of a prototype of a new district heating unit suitable for a supply temperature of 40°C with an electric booster for the domestic hot water
- Small-scale demonstration in five (5) detached and existing single-family houses in Odder, Jutland
- Continuous operation, data measurement, data collection and regular data analysis of the ultra-low district heating network for up to a year
- Demonstrate and calculate the actual reduced heat loss from the existing district heating network
- Demonstrated and calculated the actual share of electricity for producing domestic hot water in relation to the amount of room heat.

Main results from the project are:

- It works all year and keeps a high DHW comfort in the houses without complaints from the residents
- The electrical share is only 2-7 % of annual heating energy to the houses
- Reduced DH heat loss by approx. 50 % compared to traditional district heating network 80/40/8°C
- Possible to use in both low-energy but also in existing buildings
- Enables an easy way of using low-grade heat sources and introducing electricity to the district heating network.

Dansk version

Hovedformålet med projektet er at udvikle et koncept for fremtidens fjernvarmesystem, som kaldes 5. generations fjernvarme. I dette nye 5. generations- / ultralav temperatur fjernvarmesystem vil fremløbstemperaturen være ned til 40°C og retur temperaturen ned til 25-30°C. I projektet udvikles, testes og demonstreres en fjernvarmeunit med gennemstrømningsveksler og indbygget elpatron til at producere varmt vand i husene med en temperatur >45 °C.

Overordnede formål med projektet er:

- Udvikling af en ny fjernvarmeunit prototype egnet til 40°C fremløbstemperatur med en el-patron eller anden form for vandvarmer til at producer varmt vand >45°C
- Demonstration af fjernvarmeuniten og hele ultralav temperatur Fjernvarme konceptet i fem fritliggende og eksisterende enfamiliehuse i Odder, Jylland
- Kontinuert drift i de fem huse, datamåling, dataopsamling og løbende analysering af data af systemet i op til et år.
- Demonstrere og beregne det faktiske reducerede varmetab i ledningsnettet i vejen til husene
- Demonstrerer, optimere og beregne den faktiske andel af anvendt el til opvarmning af brugsvand i forhold til husene samlede varmebehov.

Hovedresultater:

- Ultralav temperatur fjernvarme konceptet fungerer efter hensigten og bibeholder indeklimakomforten og varmtvandskomforten hele året rundt uden klager fra beboerne
- Den elektriske andel til opvarmning af brugsvand udgør kun 2-7 % af husenes årlige energiforbrug til baderums opvarmning og brugsvand
- Varmetabet i det eksisterende fjernvarme ledningsnet i vejen til husene reduceres med ca. 50 % i forhold til et traditionelt fjernvarmenet 80/40/8°C og ca. 30 % i forhold til lavtemperatur fjernvarme (4. Generation) 50/30/8
- Konceptet kan anvendes både i nybyggeri, men også i eksisterende byggeri
- Åbner for nem anvendelse af enorme mængder lavtemperatur spildvarme og muliggør anvendelse af elektricitet i fjernvarmenettet.

3. Executive summary

In the last couple of years district energy has received increased awareness in energy strategy plans of governments and cities and is seen as one of the key drivers for reducing CO₂ emissions by opening up for large-scale application of renewable heat sources. When looking on the generations of DH it is clear that the supply temperature has been continuously decreasing. With the increased share of energy efficient buildings this trend is becoming a must to ensure the cost efficiency of DH systems. Lower supply temperature means not only reduced heat loss from the DH network but mainly easier exploitation of low-grade renewable sources with higher efficiency and thus better economy or utilization of huge potential of low-grade waste heat being otherwise lost.

This project "Ultra low temperature district heating with electric booster" is carried out with financial support by the Danish Energy Agency in the R&D program "EUDP". The project period is from January 2014 to March 2016.

The demonstration took place in five detached houses from 1997-99 located in Saloparken 301-309 in Odder, DK-Jutland. Three of the houses have floor heating only and two of the houses has a combination of floor heating and radiators. The demonstration was performed without changing the existing district heating pipe network in the streets to the houses. The existing district heating pipe network are pre-insulated twin pipes with same age as the houses. The 40°C supply temperature to the five houses is produced from a mixing shunt pump unit placed in the district heating network before the houses. The mixing shunt drop down the existing supply temperature from approx. 70°C down to 40°C.

The project was divided in two overall phases. The 1st phase had a duration of approx. 1 year and starts up in early 2014. The main activities of the first phase were:

1. Determination of prototype design
2. Development of prototype at Danfoss
3. Testing of prototype at Danish Technological Institute
4. Measurements and analysis – determination of the final prototype design.
5. Analysis of advantages of the electric heater concept vs. traditional and low temperature DH

The project's 2nd phase builds on the results of phase 1 with the following main activities:

1. Full scale demonstration in five houses connected to a defined pipeline networks with a central mixing shunt
2. Measurements and analysis of demonstration
3. Continuous dissemination of results and preparation of market introduction.

The demonstration has shown that the ultra-low district heating temperature is sufficient for space heating and domestic hot water production all year around.

4. Project objectives

It is documented several times that there exist a considerable amount of low temperature waste heat in Denmark and worldwide from power plants, production facilities, factories, residents areas, return water from existing district heating network etc. As most of this waste heat is low quality heat down to 30-50°C it can be difficult to utilize as a heat source.

At the same time, more and more production of electricity in Denmark comes from renewable energy – especially from wind turbines and other renewable energy sources. Because of this, the need for introducing electricity in the district heating network is raising and becoming more and more important. This can be obtained by installing electrical heat pumps in DH networks e.g. combined with a district cooling network. Alternatively, it could be obtained by producing domestic hot water in the houses by electricity.

Demonstration and expansion of low temperature district heating networks have been carried out successfully in many DH networks in recent years by COWI and several project partners using a supply temperature down to 50°C. The set point of a supply temperature of 50°C is mainly with respect to produce domestic hot water with a tap temperature at the fares end of the house installation at >45° to avoid legionella growth.

One of the main objectives of the present ultra-low temperature district heating project is to demonstrate the possibility to decoupling the need of a certain district heating supply temperature for producing domestic hot water with a tap temperature 45°C inside the houses. To produce the domestic hot water with a temperature >45°C a new district heating substation will be developed with a build in electrical booster. This will be a new, easy and cost effective way to introduce electricity in the district heating network. With a DH supply temperature equal to 40°C or lower it becomes possible to utilize the huge amount of existing waste heat in a simple way to use it directly in a DH network.

An overall summary of advantages with the ultra-low temperature district heating system are many and the most important of those are:

1. Expected significant lower heat loss in the DH network compared to traditional district heating system designs and low temperature district heating systems
2. Increased potential for renewable energy and waste heat resources, as well as higher efficiency in heat pumps, geothermal energy, etc.
3. A simple and cost effective way of introducing electricity to the district heating networks
4. Greater capacity in the district heating network, i.e. possibility of connecting more consumers
5. Reduced investment costs for new pipe network due to smaller pipe dimensions

5. Project results and dissemination of results

The first phase of the project resulted in a functional prototype design of the unit, ready for demonstration in autumn 2014. Second phase of the project started in winter 2015 by preparing the demonstration area and installing the five prototype units including measuring equipment, in the mixing shunt pump unit as well as in the houses. During spring 2015, the systems were adjusted and commissioned to be able to start the full-scale demonstration by summer 2015. The full-scale demonstration lasted until January 2016. Throughout the demonstration period, the district heating supply temperature to the area was kept at 40°C.

Annex I and II include photos and sketches of the different installations and the measuring equipment.

5.1 Indoor and domestic hot water comfort

One of the most important result is that there were no justified complaints neither about comfort of DHW nor about indoor temperature, even the outdoor temperature during January went down to -10°C. The only complain was about low indoor temperature, but the problem was identified in wrong adjustment of the electrical controller by the house owner and by wrong adjustment of the differential pressure controller in the substation. These results are very valuable for the DH company because it confirms that 40°C supply temperature is enough to keep the houses on the comfort temperature levels desired by customers. From the indoor temperature measurements, it shows that the preferred indoor temperature in the heating season is around 24°C, and in some cases, it goes up to 26°C. DHW temperature preferred by the occupants for showering was 39-40°C, confirming that 45°C DHW is enough for their comfort.

5.2 District heating substation with electrical booster

The measurements performed on the tested units revealed that the real share of electricity on DHW production was in average 30 % compared to the theoretical 23 %. The higher electricity share can be explained by the nature of the electrical heater operation. During long idling periods the heat exchanger is cooled down which increased the DHW volume needed to be heated. In one way, it increases comfort for the users by reduced waiting time for DHW, but on the other hand, it increases the share of the electricity for DHW production. The unit can be modified to delay start of the heater to the moment when the water front with proper temperature, i.e. 37°C, reach the electrical heater, at the cost of extend waiting time for the DHW with required temperature. The residents might in the future control this option. The adaptive set point of the DHW controller worked as expected and maximized the DH share for DHW heating for periods with DH supply temperature over 40°C.

Table 1 – Heat demand for space heating and DHW and share of electricity for DHW heating

Building area: 120 m ²	Construction year	Heat demand for space heating [MWh/y]	Heat demand for DHW [MWh/y]	Share of el. for DHW heating on total heating energy [%] DHW 45°C	
				Theoretical (23%)	Measured (30%)
Low-energy house	2010	6,3	1,8	5,1%	6,7%
Existing building - newer	1997	16,4	1,8	2,3%	3%
Existing building – old	1970	20	1,8	1,9%	2,5%

It should be noted that the share of electricity of the total annual heat used in the house, for space and DHW heating, is very low, only 3 %. The relative share of the electricity will however increase in case of house with lower heat demand for space heating, because the DHW part will account for higher relative share of all needed heating energy. Opposite, for houses with a

higher heat demand, the share of electricity will drop, as shown in Table 1. However, it should be kept in mind that the concept of combining DH substation with electrical DHW heater is mainly aimed for buildings with space heating system designed for maximal supply temperature of 40°C, which in most cases will not fit older existing buildings.

The average supply and return temperature from the testing area was 42°C and 34.4°C respectively, while for the adjacent area operated on the normal conditions it was 63.8°C and 52°C for non-heating period (1.4. – 15.10) and 67.2°C and 46.4°C for rest of the year. By simple calculation of heat loss based on the average soil temperature of 8°C, the annual heat loss was reduced by 40 %, which is in agreement with predicted value. However, foreseen economical contribution of reduced heat loss to the concept is reduced by fact that the cost of low-grade heat is quite low.

5.3 District heating network

Lower temperature difference between supply and return results in higher DH water flow compared to the traditionally used DH concepts. Therefore, when applying the concept of DH substation combined with the electrical heater it should be considered if we are dimensioning a new DH network or if we want to apply the concept to already existing DH network.

- For designing of a new DH network it means that dimensions of the pipes should be bigger than in case of traditional medium-temperature or low-temperature DH system and it will result in higher investment cost for the DH pipes. On the other hand, it will be compensated by lower price of low-grade 40°C heat and by reduced heat loss coming from reduced temperature levels.
- In case of applying the concept to the existing DH network the limitation might be hydronic capacity of the pipes because the network was originally designed for higher temperature difference between supply and return flow. The solution is to operate the DH with 40°C supply during non-heating and low heat demand periods. When the flow of DH water reaches the maximal hydronic capacity, the auxiliary medium-temperature heat source is needed to increase the supply temperature. However, medium-temperature heat source will result in increased cost for the heat.

5.4 Economy

The following economical analyze is made for existing DH network, considering the average DHW use of 1.8 MWh/y per house, electricity price of 0.29 €/kWh and expected price of low-grade 40°C waste heat supplying district heating at 50 % of traditional medium-temperature DH. We assume that installation of the electrical heater does not require upgrade of the main fuses. In case the existing DH network does not have enough capacity to cover, the heating demand of the buildings with supply temperature of 40°C the supply temperature will increase. The share of low-grade and medium-temperature heat at annual heat demand is considered 50 %, resulting in price level of 75 % of medium-temperature heat. However at the same time, increased DH supply temperature reduces need of electricity for DHW heating and thus we assume share of electricity on the DHW heating of 15 % instead of 30 %. The cost of DH substation with electrical heater is expected to be 585 € more compared to new state-of-the-art DH single-family house substation and additional cost for connecting the electrical part of the substation to the three phase electrical connection in the house is 135 €. Beside this, we assume 10 €/year contribution from reduced heat loss from the DH network. All prices are with VAT.

Realizing the concept for existing building with annual heat demand for space heating of 16.4 MWh/y and with 7.4 kW electrical heater the annual saving compared to the traditional medium-temperature DH solution is 455 €/y (3400 DKK/y) and simple payback time is one and half years for DH area with high heat price (see Table 2). In the area with low DH price the savings accounts for 170 €/y and payback time for four and half year. When applied in low-energy house with annual space heating demand of 6.3 MWh/y the annual saving drops to 150 €/y and payback time is increased to almost five years in case of DH area with high price. However for an area with low DH price the simple payback time increases to 43 years and thus the concept does not fit to these conditions.

Table 2 – Simple payback time and annual savings for existing DH network, various DH prices and existing and low-energy single-family house

	Existing building-newer (space heating 16,4 MWh/y)	Low-energy building (space heating 6,3 MWh/y)
DH price [€/MWh]		

Case	Medium-temperature	Ultra-low-temperature (40°C)	Annual cost for heating energy (DH + el.) [€/y]	Annual savings [€/y]	Simple payback time [y]	Annual cost for heating energy (DH + el.) [€/y]	Annual savings [€/y]	Simple payback time [y]
Reference: DH - LOW price	60	-	1090	-	-	485	-	-
DH + el. heater - LOW price	60	30	925	170	4,3	470	15	43,3
Reference: DH - HI price	120	-	2185	-	-	970	-	-
DH + el. heater - HI price	120	60	1730	455	1,6	820	150	4,8

* For existing network, the share of el is considered 15% instead of 30%, because one half of electricity is covered by medium-temperature heat.

5.5 Dissemination of project results

So far, the ultra-low temperature demonstration project has been disseminated the following ways:

- COWI Energy newsletter, December 2015
- IEA EBC Annex 64 meeting – Low exergy communities – 26/5/2016 - Aalborg
- SDDE (Slovenian District Heating Association annual conference) – 21+22/3/2016 – Portoroz, Slovenia
- IEA DHC Annex TS1 meeting: Low-temperature district heating for future energy system – workshop 23/9/2015, Nordborg
- Aalborg University in Copenhagen – 4th generation district heating conference – 25+26/8/2015
- EuroHeat & Power, article in Vol. 13 – issue 2/2016

6. Utilization of project results

District energy has for the last couple of years been receiving increased awareness in energy strategy plans of governments and cities and is seen as one of the key drivers for reducing CO₂ emissions by opening up for large-scale application of renewable heat sources. When looking on the generations of DH it is clear that the supply temperature has been continuously decreasing. With the increased share of energy efficient buildings this trend is becoming a must to ensure the cost efficiency of DH systems. Lower supply temperature means not only reduced heat loss from the DH network but mainly easier exploitation of low-grade renewable sources with higher efficiency and thus better economy or utilization of huge potential of low-grade waste heat being otherwise lost.

One of the main goals of the present project is to bring the new type DH substation to a stage where it is matured for the Danish and international market. The Danish market position within the DH technology will be maintained only if the industry continues to develop innovative solutions. Through a series of R&D projects (i.a. with Danfoss, Technological Institute and COWI as driving forces) in recent years in Denmark, low-temperature and now ultra-low temperature DH have been developed and demonstrated. This project provides an opportunity to develop and optimize the concept further, which will pave the way for much greater integration of renewable energy and waste heat resources in the Danish and foreign energy systems. The new type of DH substation and ultra-low temperature DH concept will excite international attention and pave the way for the export of Danish DH technology. Danfoss is currently looking into how the concept or new DH unit can be patented.

Based on the success of the present ultra-low temperature demonstration project a big scale project has been developed and initiated by COWI in Scandinavia. The ultra-low temperature DH system will be serving approx. 500 new build houses, which are currently under construction.

7. Project conclusion and perspective

The present pilot project showed that the developed substation combined with the electrical heater is working and the concept can under certain conditions be applied with positive economy in buildings with space heating system designed for maximal temperature of 40°C. It should be stressed that using the electricity to cover small part of DHW heating should be seen in perspective of increasing share of renewable energy in the electrical grids and also as an enabler to exploit low-grade waste heat. The amount of available low-grade industrial and renewable heat is huge and the concept is therefore seen as very promising due to the fact, that it decouples DH supply temperature from required DHW temperature and thus allows utilizing abundant sources of low-grade heat sources being otherwise lost.

- It works, keeps high DHW comfort
- Electrical share of 2-7 % from annual heating energy
- Reasonable payback time also in not “optimal case”
- DHW not as “the requirement” for minimal DH supply temperature
- 40°C supply temperature
- Reduced DH heat loss by 50 % compared to 80/40/8°C
- Improves energy efficiency of heat sources
- Enables low-grade heat sources
- It might be “NEED” for the future DH systems
- Possible to use in both low-energy but also in existing buildings.

The next step is to investigate a possible implementation on a bigger scale, and this project is already on its way to be realized. A new area in Sweden of up to 500 new houses developed initiated with an ultra-low temperature DH network with the same concept as the present small-scale project. In general, many District Heating Companies have been interested to learn about ultra-low temperature, as it makes it possible to utilize waste heat at low temperatures.



Figure 1-2 Detached house of the demonstration area.



Figure 1-3 Mixing shunt placed in the demonstration area, mixing the supply temperature to supply 40°C.

I-2 Test of prototype

As part of the product development different functionality tests were carried out at the laboratories of Danish Technological Institute, see figure 1-4, and at Danfoss' own laboratories.

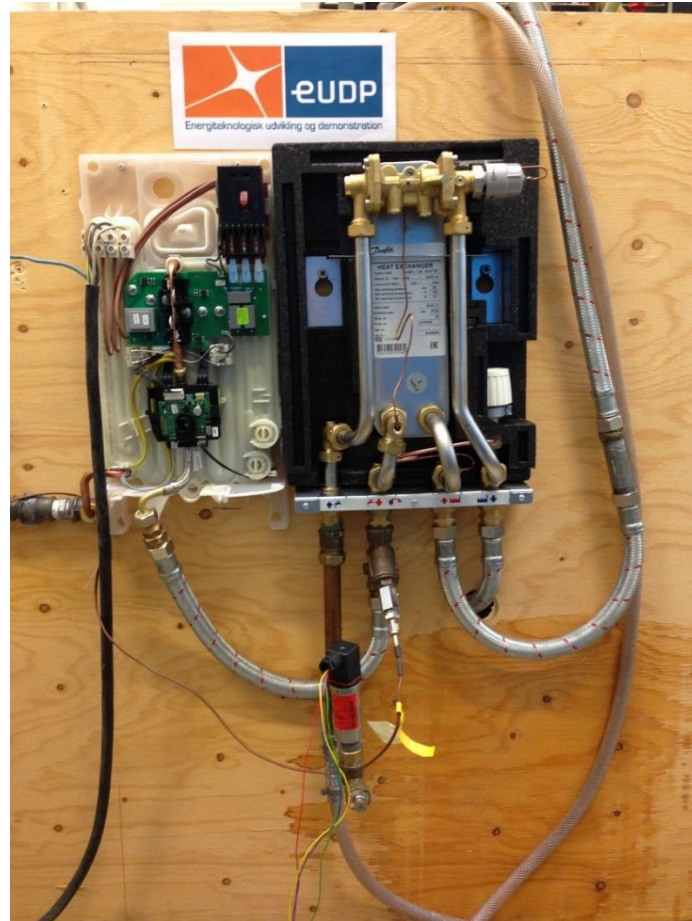


Figure 1-4 Test setup at Danish Technological Institute combining district heating water heater with electrical booster (electric instantaneous water heater)

These tests were crucial for designing and proving the prototype designs of district heating units prior installation in the demonstration area.

I-3 Measuring equipment and data acquisition

For demonstration and data acquisition, three different systems were used:

1. **In-house:** Remote readings of the district heating meter of Odder Varmeværk
2. **In-house:** Remote readings through 3G Modem of additional heat and electricity meters installed to Danish Technological Institutes own data acquisition system
3. **In mixing shunt pump unit:** Remote readings of temperature probes and heat meter through Danfoss ECL

The dedicated measuring system in each house (point 2 above), see figure 1-5, includes a heat meter on the primary side of the district heating connected water heater (V1, T11, T12) and another heat meter on the secondary side for measuring the domestic hot water consumption (V2, T21, T22). It also include an electricity meter to measure the electricity consumption of the electric booster. This setup makes it possible to measure the share of electricity used to produce domestic hot water.

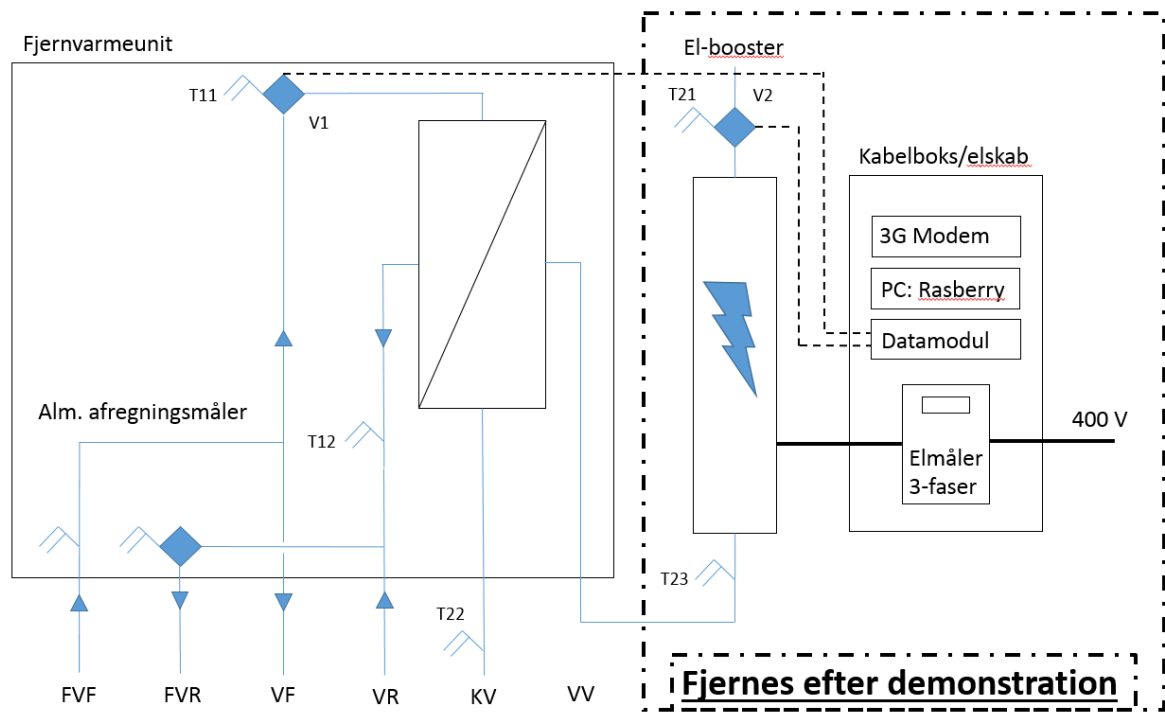


Figure 1-5 Sketch of the meters and data acquisition system installed in each house.

The data from meters and sensors are collected via Modbus, handled in a Raspberry PI computer and via 3G Modem send up to a central database. Figure 1-6 shows the different components used for the data acquisition system.

Skitse af måleudstyr til fjernvarmeinstallation i Saloparken, Odder

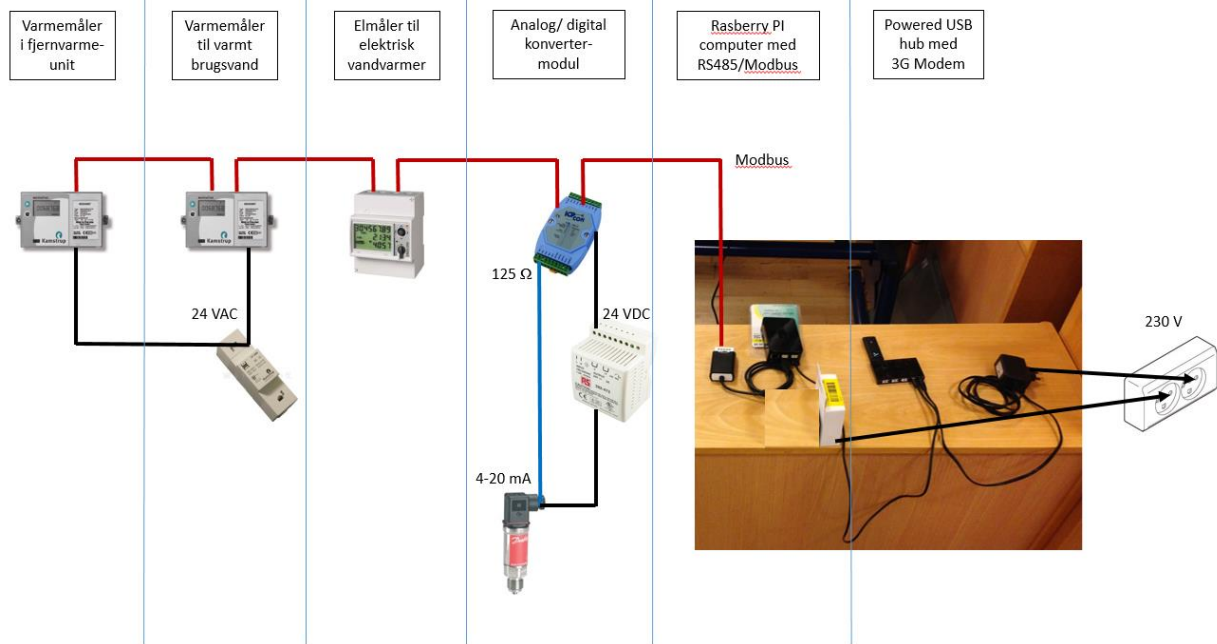


Figure 1-6 Different components and power supplies used for the in-house data acquisition systems

As all houses were different in relation to space available for the district heating unit and booster, the data acquisition systems were installed and adapted the current conditions on-site, see figure 1-7.



Figure 1-7 In-house installation of unit system with electrical booster and data acquisition system

Annex II: Presentation of the project results

**SDDE - International Conference on District Energy 2016
20 – 22 March 2016, Portorož, Slovenia**

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District Heating Substation with Electrical Booster Supplied by 40°C Warm District Heating Water

EUDP project - District Heating unit with Electrical Booster for Ultra-Low-Temperature District Heating

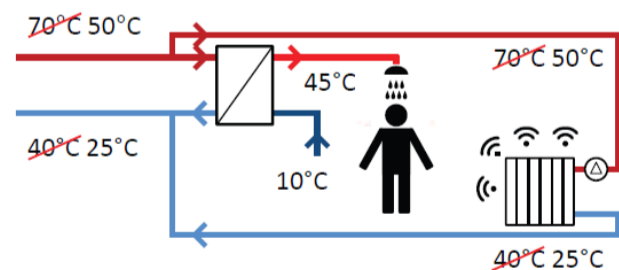


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Why reducing the DH supply temperature?

- Improves energy efficiency and better use of renewables
 - Big scale heat pumps
 - Solar-thermal plants
- Enables use of low-grade waste heat
- Reduces heat loss from DH network
 - Importance increased with reduced demand of buildings



Low-temperature district heating principle

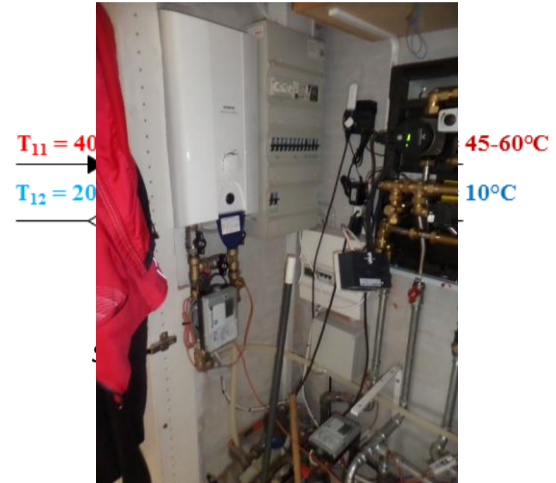
- Temperature levels:

DH supply temperatures		DH network heat loss [%]	Need of on-site heat source
>60°C	Traditional DH	100%	NO
50°C	Low-temperature DH	81%	NO
40°C	Ultra-low-temperature DH	56%	YES



Substation with electrical booster

- DH substation + instantaneous electrical heater (on DHW side)
 - DH designed inlet temperature: 40°C
 - DHW temperature: (37°C) -> 45- 60°C
 - Substation bypass: 40°C
 - DHW output: 24 kW
 - Maximal needed el. power: 6 kW
- Theoretical share of electricity on
 - DHW : (10°) ⇨ 37°C ⇨ 45°C = 23%
(10°) ⇨ 37°C ⇨ 55°C = 40%
 - Total heat demand:



Building area: 120 m ²	Construction year	Space heating demand [MWh/y]	DHW demand* [MWh/y]	Theoretical share of el. on total heating energy [%] DHW 45°C	Theoretical share of el. on total heating energy [%] DHW 55°C
Low-energy house	2010	6,3	1,8	5,1	8,9
Existing building - newer	1997	16,4	1,8	2,3	4
Existing building - old	1970	20	1,8	1,9	3,3

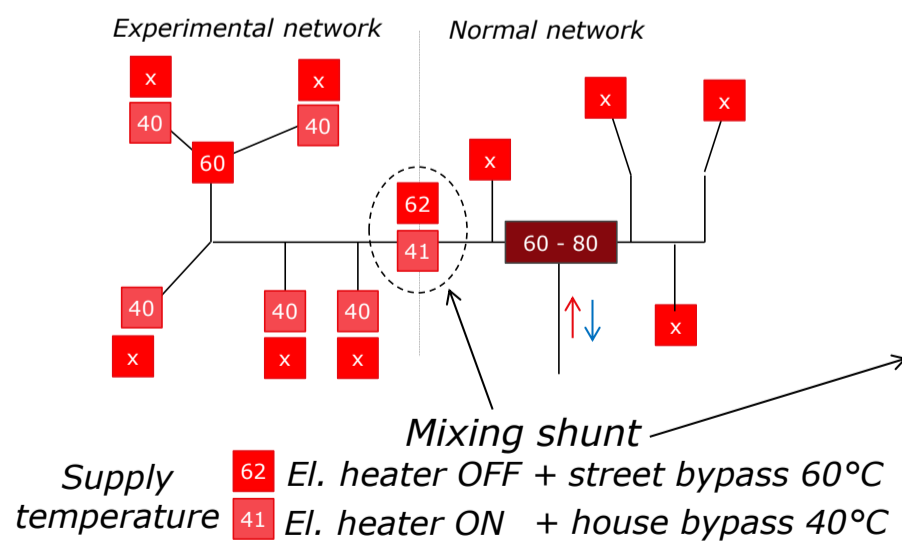
* Measured in the project

Demonstration area and conditions

- City of Odder
- Five buildings from 1997
- Mainly floor heating + few radiators
- DH network and testing conditions

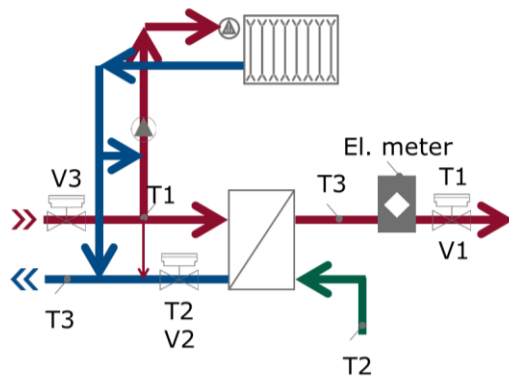


One of the buildings

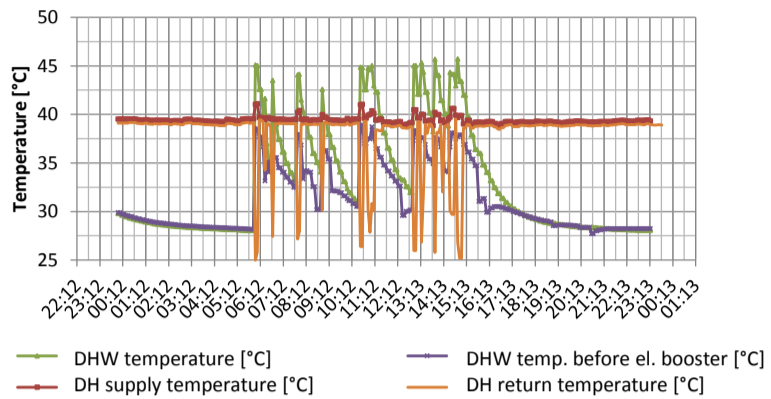


Performance – user perspective

Measuring setup



Performance of electric booster



El. share on DHW part ->

23%

30%

Building area: 120 m ²	Construction year	SH demand [MWh/y]	DHW demand [MWh/y]	Share of el. on total heating energy [%] DHW 45°C	
				Theoretical (23%)	Measured (30%)
Low-energy house	2010	6,3	1,8	5,1%	6,7%
Existing building - newer	1997	16,4	1,8	2,3%	3%
Existing building - old	1970	20	1,8	1,9%	2,5%

Economy

Lower heat price can come from:

- Low-grade heat (40°C):

- Sea water heat pump:

DH temperatures [°C]	COP [-]	Reduction in el. input [%]
80/40°C	2,9	0
50/30°C	4,2	31
40/25°C	5,2	43

- Use of low-grade waste heat in price level 100 - 400 DKK/MWh
- Return temperature reduction: Biomass CHP reduction 40 → 25°C brings 6% lower heat production price
- DH network heat loss reduction

Heat loss "60°C" vs "40°C" (summer conditions)				
DH network supply temperature [°C]	heat loss [MWh/d]	Average supply	Average return	Return temp during idling [°C]
62°C	0,056	61,1	57,5	58
41°C	0,033	42,0	35,5	37
Heat loss reduction [%]	41%			

Example – existing building (1997)

- Floor heating system, supply temperature 40°C whole year

Case	DH price		Existing building-newer (space heating demand 16,4 MWh/y)			Low-energy building (space heating demand 6,3 MWh/y)		
	Medium - tempera- ture [€/MWh]	Ultra-low- temperatu- re (40°C) [€/MWh]	Annual cost for heating energy (DH + electricity) [€/y]	Annual savings [€/y]	Additional simple payback time	Annual cost for heating energy (DH + electricity) [€/y]	Annual savings [€/y]	Additional simple payback time
medium temp DH LOW price	60	-	1092	-	-	486	-	-
DH 40°C + el. heater LOW price	-	30	638	454	1	335	151	3,1
medium temp DH HI price	120	-	2184	-	-	972	-	-
DH 40°C + el. heater HI price	-	60	1176	1008	0,5	570	402	1,2

Electricity price: 0,29 €/kWh , unit price: 585€ addition to standard LTDH substation

- Electrical booster enables lower price for district heating through higher heat source efficiencies and reduced heat loss from DH network

Next steps

- Continue with testing and improvements
- More economical analyzes
- Make it as a product
- Find out how long we can run with 40°C supply temperature

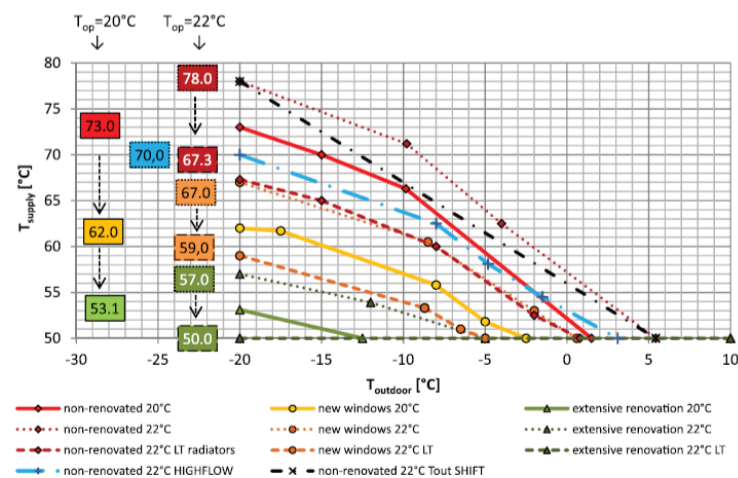


Fig. 3. Supply temperature curves for all the investigated cases.

Source: Renewable-based low-temperature district heating for existing buildings in various stages of refurbishment, Brand M, Svendsen S. in Energy 2013, vol. 62, p. 311-319.

Conclusions

- It works, keep high DHW comfort
- Electricity share 2-7% from annual heating energy
- Reasonable payback time
- DHW not as "the requirement" for minimal DH supply temperature
- 40°C supply temperature:
 - Reduced DH heat loss by 50% compared to 80/40/8°C
 - Improves energy efficiency of heat sources
 - Enables low-grade heat sources
- It might be "NEED" for the future DH systems
- Possible to use in both, low-energy but also existing buildings

Thank you



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