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A New Low-Temperature District Heating System for Low-Energy Buildings

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ABSTRACT

This paper describes the possibilities in using District Heating (DH) for low-energy houses. The challenge is to design a cost-effective system with a very low heat loss, which can supply sufficient DH temperatures all the year round to an urban area of houses with low energy demand for space heating. The solution seems to be a low-temperature system consisting of small and well-insulated twin pipes. Traditional design parameters for DH networks have been reviewed. An analysis of a low-energy house and DH network has been carried out. The paper presents main design parameters and results for energy consumption and economy. All results presented in the paper are preliminary.

INTRODUCTION

The focus on energy efficiency and savings is increasing globally. The European Union energy policy gives high priority to energy savings and use of renewable energy. 40% of all energy consumption takes place in buildings, so this is one of the main target areas. In Denmark, the government has decided that energy use in new buildings must be reduced stepwise by 25% in 2010, 2015 and 2020. With the increasing number of new low-energy houses the question is: "What kind of heat supply is economically and environmentally most attractive?" In urban areas with DH, it might be reasonable to connect some new low-energy houses. But in new subdivided areas with many or only low-energy houses, it is interesting to know if it is feasible to use DH. Today in Denmark, low-energy houses located in DH districts can be exempted from connection obligation to the DH network. Therefore, it is relevant to research if DH is a good alternative to other heating technologies, e.g. heat pumps.

The low heat demand in low-energy houses means that the network heat loss may be a very significant part of the total heat demand with a traditional network design. To solve this problem, the network heat loss and involved costs must be reduced. The solution seems to be a low-temperature DH network with high-class insulated twin pipes in small dimensions, ref. Svendsen, S., Olsen, P.K. and Ærenlund, T. (2005-2006).

The advantages of a low-energy DH system are:

- DH is a flexible system suitable for all kinds of energy sources;
- Renewable Energy (RE) sources can be used directly or in combination with large-scale heat storages. This means that DH can be an important part of the future energy supply system fully based on RE;
- Great potential for utilisation of waste heat from CHP plants, refuse incineration and industrial processes;
- DH covers a large part (60%) of Denmark's heating supply and is a well-known technology;
- DH is reliable and easy to operate for the consumers.

In a Danish governmentally founded project (EFP2007) “Development and Demonstration of Low-Energy District Heating for Low-Energy Buildings”, a new concept for low-energy DH systems is being investigated and designed. This paper gives some of the design parameters and results achieved in the project, where the following is analysed:

- Heat demand in low-energy houses;
- Consumer unit (see separate paper);
- Pipe types and DH network system.

A new type of consumer unit (DH installation for space heating and with a storage tank for DH water to domestic hot water delivery) is described in a separate paper for the symposium: "Consumer Unit for Low-Energy District Heating Networks".

This paper deals with the overall system concept for a DH network to low-energy houses. The heat demand in a low-energy house, the network design parameters and the network are analysed with respect to energy consumption and economics. The paper does not go into detail about the design of the consumer unit, but because the consumer unit has a substantial influence on the DH network design, three types of unit designs are considered in different scenarios. The three types are:

- DH storage unit (new type of unit);
- Heat exchanger unit (no heat storage);
- Domestic hot-water storage unit.

In general, it has been necessary to set up many assumptions for the project analyses. A reference house has been defined, and a reference urban area has been selected. The area involves 92 low-energy houses, for which the low-energy DH system is optimized with respect to both the energy used for pumping and the heat loss from the pipes. In addition to the design results of the low-energy DH network, the paper further presents a socio-economic comparison with heat pumps.

All results presented in the paper are preliminary, because the project is ongoing. Adjustments of results may therefore occur at a later time.

REFERENCE HOUSE & URBAN AREA

The reference house

The DH consumption in the network depends very much on the type, size and number of connected houses. In addition, also the number of people living in the houses and their behaviour have influence on the heating consumption and network design.

It was selected to use a 145 m^2 one-storey house as reference house in the network. This is not a very large house, many new houses are larger, but the idea was that if it is possible to make a cost-efficient district heating system to this size of houses, then the concept will be suitable for most new houses in general. Smaller houses are being built, but they are often terraced houses, which are built closer together. That gives a higher heat density in the network system, shorter pipe lengths and smaller network heat losses per house compared to individual houses.

The selected house is a low-energy house Class 1, which refers to the building standard in the Danish Building Regulation with the so far strictest requirement to energy consumption. The energy requirement for maximum yearly consumption is seen below.

Table 1. Overall definition of low-energy houses Class 1.

Definition of a low-energy house Class 1
35 + (1100 / A) kWh/m^2 per year
A is gross heated floor area

The definition for a 145 m^2 house: 42.6 kWh/m^2 per year

The definition includes energy for space heating, domestic hot water, cooling and electricity for installations (pumps and ventilation). With renewable energy sources, like solar heating, it may be allowed to use more energy than the definition prescribes.

The maximum energy consumption for low-energy houses Class 1 is in theory 50% lower than for standard new houses.

The space heating demand of the reference house was calculated with the simulation program "Bsim". The model of the reference house in Bsim is illustrated in Fig.1. Normally in theoretically calculations and for documentation of compliance with the definition (given above), an indoor temperature of 20°C is used in all heated rooms. For the reference house, it gives a theoretical heating demand of 3028 kWh per year (20.9 kWh/m^{2}year). In practice, the conditions often are different, though. So, more realistic temperatures are assumed to be 24°C in bathrooms and 22°C in the rest of the house. This may not seem like a big difference, but in a low-energy house, it gives a significantly increased heating demand compared to the total demand. With the higher room temperatures, the energy demand for space heating in the house is 4450 kWh per year (30.7 kWh/m^{2}year), which is almost 50% higher than for the case with 20°C in all rooms.

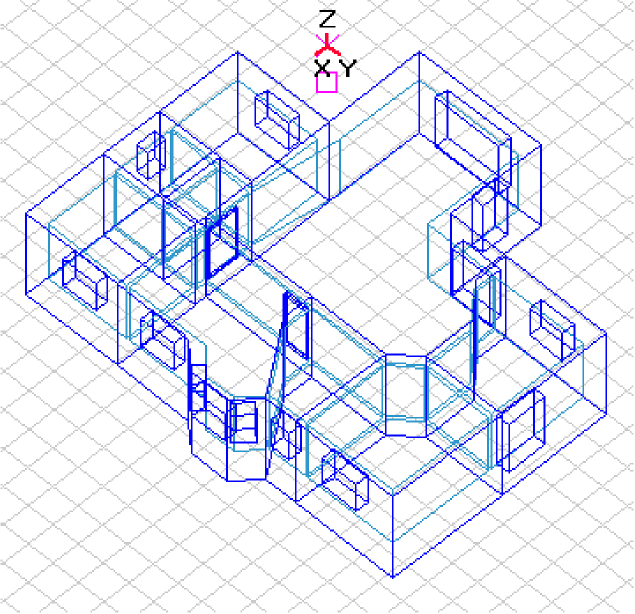

Fig. 1. Bsim-model of reference house.

To get the total district heating demand for the reference house, it is necessary also to define the domestic hot water demand. Based on statistics and experience, the demand is specified to be 2300 kWh per year, which corresponds to about 155 litres per day of 45°C hot water.

In total, the yearly average heating demand of the reference house is calculated to be 6750 kWh, where space heating accounts for 66% and domestic hot water for 34%.

Table 2. Total heating demand for the reference house.

Heating consumption	*kWh/year*
Domestic hot water	2300
Space heating	4450
In total	6750

The range of space heating demand during the year is illustrated in Fig. 2.

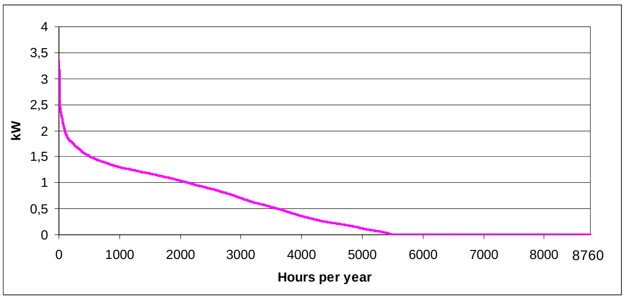

Fig. 2. Duration curve with the hourly averaged space heating demand in the reference house (145 m^2).

It is seen that the peak demand (coldest day of the year) is 3.4 kW. Daily averaged values would be a little lower and could be acceptable for houses with floor heating, because such a building construction can accumulate the heat and therefore counteract large indoor temperature drops. In order not to lock the concept on houses with floor heating in all rooms, it was decided to use the hourly averaged values.

The reference urban area

An urban area has been selected for reference. The area is located in a new district called Ullerød-byen in Hillerød Municipality, Denmark. The area is at planning stage, but is expected to have a great focus on energy efficiency regarding both buildings and energy supply. Fig. 3 shows the area of Ullerød-byen, where a subarea has been picked as case for this low-energy DH project. This area consists of 92 low-energy houses Class 1.

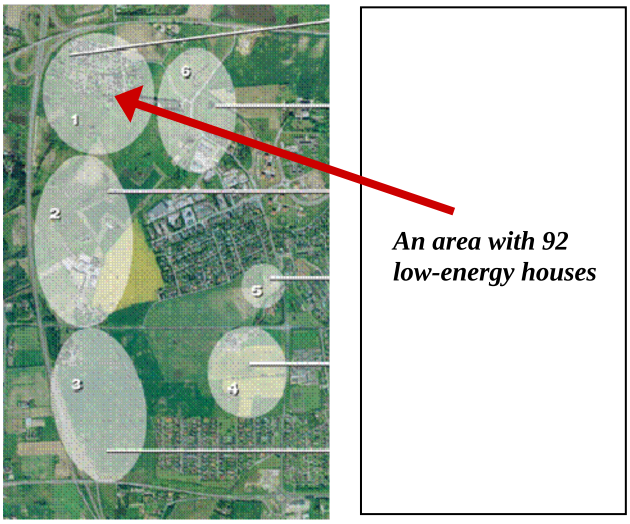

Fig. 3. Selected area for network in Ullerød-byen (Denmark).

DH STORAGE UNIT

The philosophy with the DH storage unit is that lower DH temperature is required, and only a constant very low DH supply (flow) is necessary. The flow for the DH storage unit to cover the heating of spaces and domestic hot water is illustrated in Fig. 4 for 8 different demand rates.

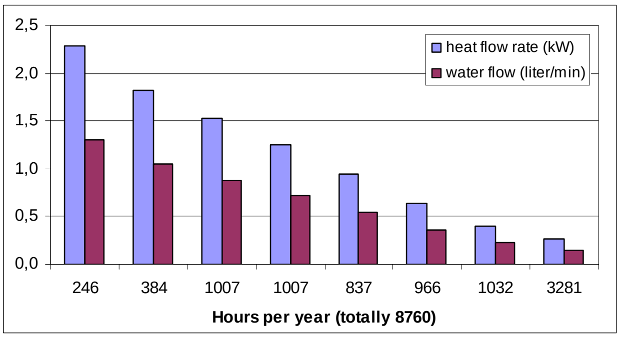

Fig. 4. Average hourly values for heat-flow rates and water flows for the DH unit in the reference house during the year.

The lowest interval covers the summer period, when there is only demand for domestic hot water. Remaining is about 7.5 months with space heating demand - "the heating season". Again, to illustrate the influence of the indoor temperature, it could be mentioned that in the theoretic case with only 20°C, the heating season is calculated to be about one month shorter.

The heat-flow rates and water flows on Fig. 4 are very small compared to traditional units and houses. This is because the heat-flow rate to the domestic hot water is levelled out to constantly being about 0.26 kW. All fluctuations are absorbed in the tank. The low heat-flow rate at 0.26 kW corresponds to about 9 litres per hour in a district heating system with 50°C supply and 25°C return. That is only 0.15 litres per minute, which can be described as "one cup per minute".

For further details on the DH unit, please see separate paper: "Consumer Unit for Low-Energy District Heating Networks".

DH PIPES

A network for low-energy houses cannot be made exactly the traditional way, because this will result in relatively large network heat losses. Lower heat losses can be accomplished through the following parameters:

- Smaller pipe dimensions
- Larger insulation thickness
- Highly-efficient PUR insulation
- Cell gas diffusion barrier
- Diffusion-tight flexible carrier pipe
- Twin pipes (double pipes)
- Reduced pipe lengths, if possible.

To optimise the pipe system with respect to costs, it has been important to look at the piping. Besides the lower heat loss, the usage of twin pipes further has the advantage of reducing the material and construction costs. This paper does not concern the actual piping methods, but further investigation might reveal if for example pipe laying with chain-digger machines can reduce construction costs even more.

Two types of pipes are selected for the network: Flexible pipes and (bonded) steel pipes. Both types are twin pipes, which are supply and return in one casing pipe. The flexible pipes are available with dimensions of the service pipes of ø14-32 mm. Steel twin pipes in straight length of 12-16 metres are used for larger dimensions. They are available in service pipe dimensions up to ø200 mm. It should be mentioned that the ø14 flexible pipe is not on the Danish market yet, but will be developed and produced for testing in this project by LOGSTOR A/S.

Several designs of flexible pipes are on the market, but in this project, it was decided to focus on a type with a service pipe of the multi-layer type containing aluminium and PEX (cross-linked polyethylene). The manufacturer uses the name "AluFlex" for this type of DH pipe. This type is combining the advantages of the smooth surface of the plastic pipe with the durability and tightness of the welded aluminium pipe. The service pipe is a sandwich construction, consisting of an aluminium pipe, coated inside with PEX and outside with PE. The aluminium core protects 100% against cell gas diffusion into the media and water vapour diffusion into the insulation. It further makes the pipe dimensionally stable during installation in the trench and during installation of the force transmitting press-couplings. Flexible DH pipes with regular PEX service pipes do not have the tightness property to avoid cell gas and water vapour diffusion.

The other type of pipe is a steel pipe, which has a pipe of steel as service pipe, which is diffusion tight itself.

The flexible twin pipes in the dimensions 14 to 32 mm as well as the straight pipes in larger dimensions are chosen as the continuously produced type with low-lambda PUR insulation and an aluminium diffusion barrier between the insulation and the PE casing. Because the insulation is encased between the outer diffusion barrier and the diffusion-tight media pipes, there will be no loss or contamination of the cell gas. The very low heat conductivity will therefore remain unchanged over time.

Pipe data

The pipe data in Table 3 have been assumed for network design and calculations of network heat losses. The values in the table are delivered by LOGSTOR.

Table 3. Pipe data for two used DH twin pipe types.

AluFlex twin pipe - Class 2		
Pressure class PN10		
Dimension (carrier pipe)	Casing pipe diameter	Heat loss
d_{supply}-d_{return}	D	Total
mm	mm	W/m
14-14	110	2.84
16-16	110	3.09
20-20	110	3.66
26-26	125	4.05
32-32	125	5.07

Steel twin pipe - Class 2		
Pressure class PN25		
Dimension (carrier pipe)	Casing pipe diameter	Heat loss
d_{supply}-d_{return}	D	Total
mm	mm	W/m
42-42 (DN 32)	182.7	4.96
48-48 (DN 40)	182.7	5.81
60-60 (DN 50)	227.9	5.62
76-76 (DN 65)	256.1	6.57
88-88 (DN 80)	283.8	7.34

The heat losses in the table are valid for $T_{supply}/T_{return}/T_{ground}$ = 55/25/8°C and represent the total loss for both supply and return. At these temperatures, the heat loss from the return pipe is zero or negative, which is due to a small amount of heat transferred from the supply pipe to the return. In general, the heat losses listed in the table are very low.

Validation of pipe heat loss (FEM calculation)

For AluFlex pipes, LOGSTOR guarantees a maximum thermal conductivity of 0.023 W/(mK), and for steel twin pipes 0.024 W/(mK). However, due to the low temperature level in the pipes, the thermal conductivity will be lower than the above given values. In Fig. 5, the thermal conductivity is shown as a function of temperature for polyurethane (PUR) foam.

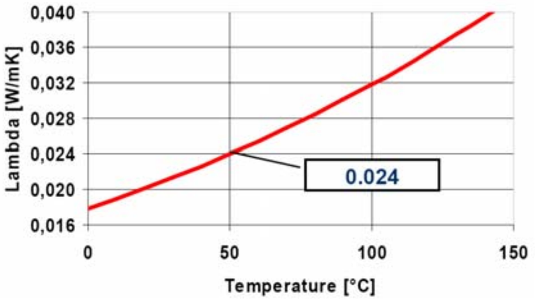

Fig. 5. Thermal conductivity as a function of temperature for LOGSTOR PUR conti-foam.

The heat loss values in Table 3, supplied by LOGSTOR, have been calculated by the Multipole-Method, in which the thermal conductivity is adjusted by iteration until it fits with the assumed temperature of the PUR-foam.

In the following, the theory behind heat loss calculations and the Multipole-Method is described.

In case of co-insulated pipes (circular twin pipes) the heat loss can be calculated from:

Supply: $q_s = U_{1s} (T_s – T_g) - U_2 (T_r – T_g)$
Return: $q_r = U_{1r} (T_r – T_g) - U_2 (T_s – T_g)$

U_{ij} is the linear thermal transmittance, or the heat loss coefficient, cf. Bøhm and Kristjansson (2005).

For carrier pipes of equal size and placed horizontally, $U_{1s} = U_{1r}$. In that case, the total heat loss is calculated from:

$$q_{tot} = q_s + q_r = 2 (U_1 - U_2) \left[\frac{Ts + Tr}{2} - T_g \right]$$

For the case with horizontally placed twin pipes, the heat loss can be calculated by the approximate equations by Wallentén (1991). For vertically placed carrier pipes, the MultiPole-Method by Claesson and Bennet (1987) can be used in case of constant thermal conductivity.

The above equations can be reformulated as:

Supply: $q_s = [U_{1s} - U_2 (T_r – T_g)/(T_s – T_g)] \cdot (T_s – T_g) = U_3 \cdot (T_s – T_g)$
Return: $q_r = [U_{1r} - U_2 (T_s – T_g)/(T_r – T_g)] \cdot (T_r – T_g) = U_4 \cdot (T_r - T_g)$

The advantage is that the heat losses from each line (pipe) are calculated by one temperature difference, however, the new heat loss coefficients U_3 and U_4 are temperature dependent. Next, the temperature-dependent heat-loss coefficients can be used by simulation programmes such as TERMIS, which is not capable of using two heat loss coefficients for each line.

The Multipole calculations have been compared with the Finite Element Method (FEM) used in the software program Therm. To the left, Fig. 6 shows a model of a 14-14/110 mm twin pipe with three sections of different thermal conductivities as defined in Fig. 5. The middle section of Fig. 6 shows the temperature distribution in the twin pipe. Finally, the right section shows the heat fluxes for the return carrier pipe. It appears that a heat flow enters the return pipe from the supply pipe below, and that another heat flow leaves the return pipe at the top.

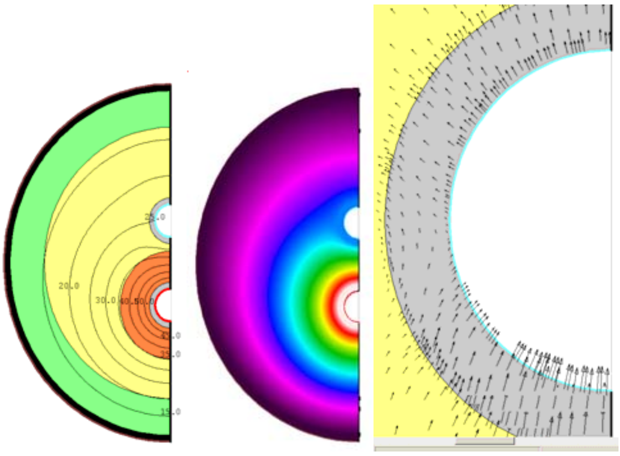

Fig. 6. FEM simulation of a 14/14/110 mm twin pipe with the return pipe placed above the supply pipe. Model with three layers of different conductivity to the left. Isotherms in the middle part, and heat fluxes to the return pipe to the right.

The results of FEM calculations indicate slightly higher heat losses than stated in Table 3. Still the values in the table do not deviate more than what is acceptable for usage in the DH network analyses.

DH NETWORK

Intro

System design for the DH networks has been optimised from at hydraulic point of view by the use of the simulation software TERMIS. Three scenarios have been analysed with respect to design of the DH network:

- Scenario 1: Network for DH storage units (new type of unit);
- Scenario 2: Network for heat exchanger units (no heat storage);
- Scenario 3: Network for domestic hot water storage units.

Routing of DH network including 92 consumers (end nodes) are illustrated in the following figure.

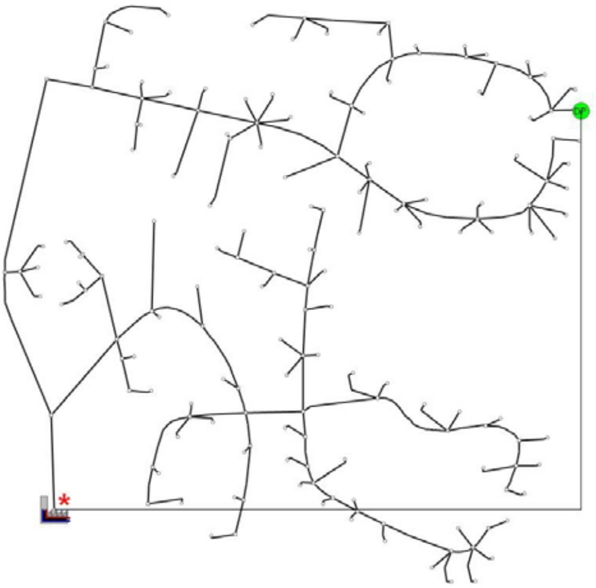

Fig. 7. Simulated network for the reference area.

Routing has not been optimised with respect to pipe lengths, but is made in the traditional way.

Network design methodology and assumptions

Basic design methodology is to minimise pipe dimensions until the 10-bar pressure limit is reached in a peak-demand situation. The peak demand varies for the three different unit types and therefore allows different network designs. The following main assumptions are made for the DH network analyses:

- 10 bar system (maximum pressure)
- Holding pressure: 2 bar
- No limits for pressure gradients
- Maximum velocities: 2 m/s
- Low-energy houses, Class 1 (Danish Building Regulation).

Additionally, assumptions for peak demand (design load) and temperature sets are listed in the following table.

Consumer unit type	Design load	Design temperatures	
		T_{supply}	T_{return}
DH storage	3.7 kW	50°C	22°C
Heat exchanger	32 kW	50°C	22°C
Domestic hot water storage	8 kW	60°C	30°C

Different peak demands at the consumer unit allow different dimensions for pipes in the network and especially the house entry pipes. Dimensions of the main pipes are also dependant on the simultaneity factor for domestic water consumption. The simultaneity factors differ for each consumer unit.

The designing process for the DH network is the following:

- Heat demand is defined at consumer notes with respect to simultaneity factors;

- Network pipes are chosen in a hydraulic optimisation. Some of the inputs for the hydraulic optimisation are maximum system pressure, pipe- and pump data;

- Heat losses are calculated for 8 intervals representing main yearly variations in e.g. heat demand;

- Pipe dimension corrections can be done during the designing steps if the results are not satisfactory.

Network design - results

Routing of pipes is the same for the three different scenarios, but the pipe dimensions are different. The following tables illustrate pipe types, lengths, prices (Copenhagen area) and pump expenses for the three scenarios. The pipe prices per metre routing are delivered by LOGSTOR and COWI.

Table 4. Results of pipe dimensions, length and prices of Scenario 1, DH storage unit.

Pipe type	*Length [m]*	*Price per metre routing [DKK]*	*Total per type [DKK]*
Alx 14-14/110	1,566	1,199	1,877,838
Alx 16-16/110	205	1,199	245,741
Alx 20-20/110	242	1,228	296,832
Alx 26-26/125	440	1,535	674,824
Alx 32-32/125	147	1,562	230,208
Steel-DN32	412	1,778	732,705
Steel-DN40	137	1,822	249,988
In total	3,214	-	**4,308,135**

Table 5. Results of pipe dimensions, length and prices for Scenario 2, Heat exchanger unit.

Pipe type	*Length [m]*	*Price per metre routing [DKK]*	*Total per type [DKK]*
Alx 20-20/110	2,296	1,228	2,819,979
Alx 26-26/125	230	1,535	353,204
Alx 32-32/125	73	1,562	114,252
Steel-DN32	549	1,778	976,655
Steel-DN50	65	1,982	128,830
In total	3,214	-	**4,392,921**

Table 6. Results of pipe dimensions, length and prices for Scenario 3, Domestic hot water storage unit.

Pipe type	*Length [m]*	*Price per metre routing [DKK]*	*Total per type [DKK]*
Alx 14-14/110	1,781	1,199	2,135,923
Alx 16-16/110	127	1,199	152,201
Alx 20-20/110	361	1,228	443,805
Alx 26-26/125	280	1,535	429,608
Alx 32-32/125	50	1,562	78,123
Steel-DN32	549	1,778	976,655
Steel-DN40	65	1,822	118,430
In total	3,214	-	**4,334,746**

It is confirmed that the DH storage unit in general requires smaller piping than the two alternatives. However, it should be noted that the total investments for the three scenarios are very similar. This is because the prices of small pipes and laying of them are the same or very similar.

The pipe dimensioning is based on system limits of 10 bar and a holding pressure of 2 bar. This allows a system differential pressure of 8 bar for 92 houses, which is larger than for traditional systems, but also allows very small pipes. Fig. 8 gives an example of the pressure profile on the critical route in a peak-load situation. The viewed profile is taken from Scenario 1 (DH storage unit).

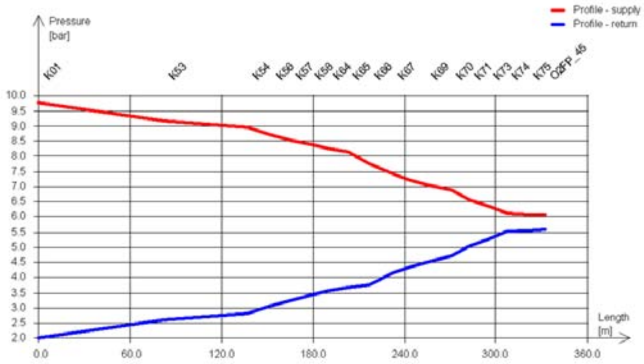

Fig. 8. Pressure profile on critical network route for Scenario 1, DH storage unit.

The system will only peak to the 10 bar limit very few hours of the year.

Table 7 below gives a summary of the analysis results for the three scenarios. The heat loss percentage is calculated on basis of the heat delivered to the network.

Table 7. Results of energy, total network.

Energy in DH network	*Scenario 1 DH storage unit*	*Scenario 2 Heat exchanger unit*	*Scenario 3 D. hot water unit*
Heat consumption, per house [kWh/year]	6,750	6,750	6,750
Heat consumption, total network [kWh/year]	621,000	621,000	621,000
Heat delivered, total network [kWh/year]	687,920	720,790	721,105
Heat loss, total network [kWh/year]	66,914	99,785	100,100
Heat loss, total network [%]	**10**	**14**	**14**
Electricity consumption for pumping, total network [$\text{kWh}_{\text{electricity}}$/year]	7,006	3,731	4,768

The interesting results of the table are the heat loss percentages. The heat losses for all three scenarios are very low, especially considering the low heat consumption in the low-energy houses. It is either 10% or 14% of the heat delivered to the network. Scenario 1, DH storage unit, has the lowest heat loss, because of both low water flows and low temperature. Scenario 2, heat exchanger unit requires larger peak water flows. And Scenario 3, domestic hot water storage, requires higher DH temperature in order to avoid problems with Legionella.

Summer heat losses are based on the same supply temperatures as winter heat losses because a bypass arrangement will ensure the same supply temperature at the consumer all year. The return temperature will increase slightly during the summer due to the bypasses.

Important to observe is that the calculated heat losses are theoretical values. Practical experience shows that real heat loss will be higher. It is estimated, that the real heat loss in a (traditional designed) DH network could be 20-30% higher. Pipe connections and components might be some of the explanation.

The investment costs of the three scenarios are listed in the table below. For each scenario is presented the estimated costs, consisting of costs of the pipe system, of pumps in a substation, of the consumer supply line installation and of the consumer unit. All costs are without VAT. The component prices are delivered by LOGSTOR, DANFOSS, Grundfos and COWI.

Table 8. Economy for network, total investment costs[DKK].

DH construction costs [DKK]	*Scenario 1 DH storage unit*	*Scenario 2 Heat exchanger unit*	*Scenario 3 D. hot water unit*
Pipe system	4,308,135	4,392,921	4,334,746
Main pumps	105,000	105,000	105,000
Consumer supply line installations	391,552	391,552	391,552
Consumer unit	2,539,200	1,788,480	1,876,800
In total	**7,343,887**	**6,677,953**	**6,708,098**
In total per house	**79,825**	**72,586**	**72,914**

It is assumed that the new network is connected to an existing network.

The consumer unit costs for Scenario 1 include a 200 litre storage tank, a domestic hot water heat exchanger, an electronic control, pumps and insulated cover. For Scenario 2, the unit cost is lower because no storage tank is required. In Scenario 3, the consumer unit is a DH unit with less and more simple components including a 150 litre storage tank for domestic hot water.

The conclusion of the economy results in Table 8 is that Scenario 1, DH storage, has the highest unit investment costs. On the other hand, this scenario entails the lowest network heat loss.

SOCIO-ECONOMICS

In this paragraph, the low-energy DH concept is compared with an alternative heating technology suitable for low-energy houses. The comparison is done in a socio-economic calculation. Two types of heat pumps are selected for the comparison. The reason for that is that the market for heat pumps is growing, and they are quite cost-efficient. The disadvantages of the heat pumps are that they rely on power supply, and they have a poor potential for usage in combination with other heat sources such as solar heating and waste heat from CHP plants, refuse incineration and industrial processes.

The three selected scenarios used in the comparison are:

- Low-energy DH (with DH storage units)
- Heat pump, ground coil
- Heat pump, air-to-water.

The DH storage unit (Scenario 1) is selected for the comparison with heat pumps, because of the advantage of lower heat loss.

The ground coil heat pump is a concept with the ground as a heat source and electricity as drive power. The system has horizontal pipes in the ground in approximately 1 metre depth, which are connected to a unit with a heat pump placed inside the house.

The air-to-water heat pump utilises the outdoor air as heat source. The system consists of a unit part placed outside connected to another unit part with a heat pump mounted inside the house.

General assumptions

It has been necessary to make a number of assumptions for the socio-economic calculation. The method and the main overall assumptions used for calculating the socio-economy are given by the Danish Energy Authority. The economy is calculated for a 30-year period.

Main overall assumptions:

- Real interest rate: 6%
- District heating price in 2008: 69,44 DKK/GJ (248,4 DKK/MWh)
- Electricity price (household) in 2008: 729 DKK/MWh
- Electricity price (company/plant) in 2008: 654 DKK/MWh

Specific assumptions for low-energy DH:

- Lifetime of DH pipes: 30 years
- Lifetime of main DH pumps: 20 years
- Lifetime of consumer unit and house installations: 30 years with small re-investment after 15 years (5000 DKK)
- DH network operation and maintenance costs: 120 DKK/kWh

Specific assumptions for ground coil heat pump:

- Season Performance Factor: 3,1
- Lifetime, consumer unit and house installations: 30 years with 50% re-investment every 10 years (20,000 DKK)

Specific assumptions for air-to-water heat pump:

- Season Performance Factor: 2,5
- Lifetime, consumer unit and house installations: 30 years with 50% re-investment every 10 years (20,000 DKK)

Component prices and data for the heat pumps are delivered by COWI, IVT naturvarme and Vølund Varmeteknik (NIBE AB).

Costs of DH plant and power plant capacity are included in the energy prices.

National values from the Danish Energy Authority are used to calculate the costs of fuels, taxes and emissions.

Results

The socio-economic results for comparison are given in the table below. The calculation is made for a 30-year period, and assumed necessary re-investments are therefore added to the investments.

Table 9. Socio-economic costs in a 30-year period for three scenarios [DKK].

Costs per 30 years [DKK]	Scenarios		
	Low-energy DH unit	Heat pump, ground coil	Heat pump, air-to-water
Investment and re-investment	8,859,661	12,753,078	10,775,193
Maintenance and operation	188,465	0	0
Fuel, taxes, emissions etc.	3,389,597	2,520,551	3,125,483
In total	**12,437,723**	**15,273,629**	**13,900,676**
per house	**135,193**	**166,018**	**151,094**

With the used assumptions, it is a fact that low-energy DH is competitive with the heat pump technology.

CONCLUSION

The first results of this project indicate that an optimized DH system for low-energy houses is competitive with other heat sources from a socio-economic point of view.

This conclusion is based on detailed analyses of:

- Heat demand in a low-energy house, Class 1
- DH storage unit (not this paper)
- Twin DH conti-pipes
- DH network.

Main parameters for traditional DH system design have been reviewed and in some cases adjusted. The paper illustrates that in theory it is possible to obtain a low network heat loss although all houses connected to the DH system have a very low heat demand.

It can also be concluded that the difference between the DH unit types is rather small regarding total investments. However, the DH storage unit scenario has lower network losses.

Next phase of this project is demonstration of the DH storage unit and the 14-14/110 mm flexible DH pipe.

Finally, it should be repeated that all results presented in the paper are preliminary, because the project is ongoing. Adjustments of results may therefore occur at a later time.

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