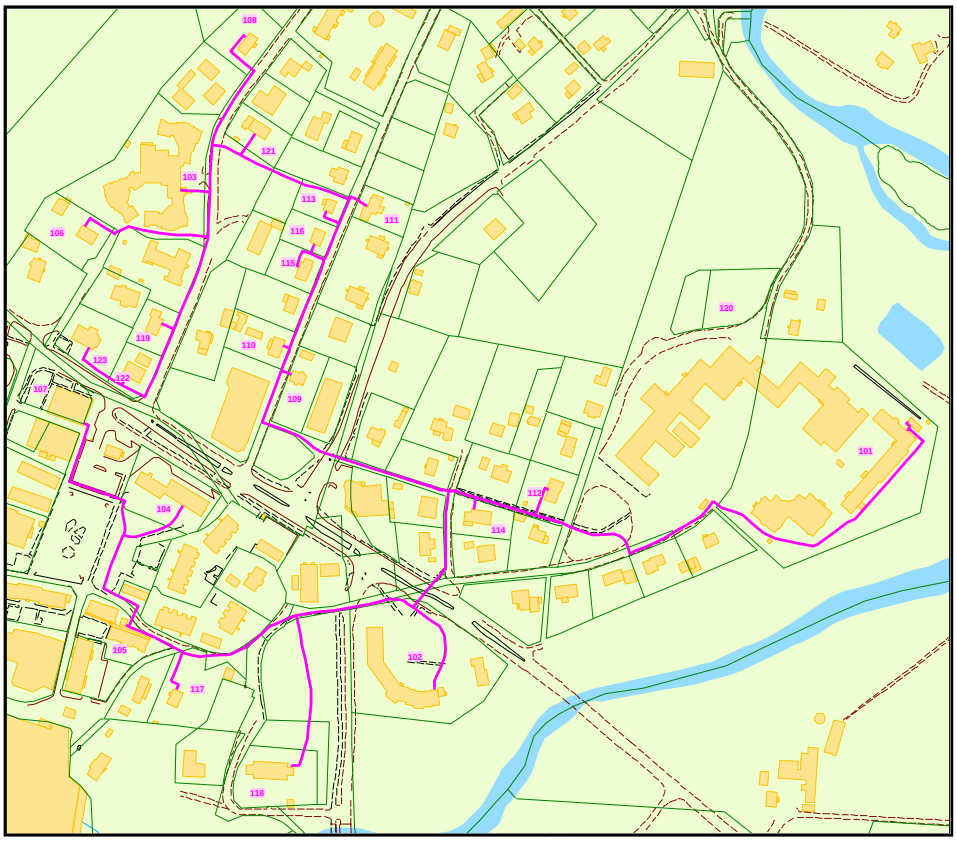
Report-evaluation of a small scale district heating system in Ullared, Sweden



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Energy in Minds is a project of the Concerto initiative co-funded by the European Commission within the sixth Framework Program.

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Abstract

This evaluation and final report is a part of an EU-project, "Energy in Minds" (EiM). The project is a part of the EU-programme Concerto within the Sixth Framework Programme. EiM has been running from 2005 and is now finalized in May 2010. Within the EiM project, the local energy company, Falkenberg Energi AB (FEAB), has received EU-funding of totally 98 200 Euro for the two local heating systems consist of a completely new small scale district heating system in Ullared and one partly new in Vessigebro, in the north-east part of the municipality of Falkenberg. The system in Ullared, which this report is focusing on, a prefabricated transportable heating plant with a boiler of 1500 kW has been installed. The fuel used is pellets. The pipe network consists now of about 2,5 km of double pipeline. 22 customers have been connected so far, representing a heat demand of about 2400 MWh annually. The main customers are the school building, health care centre, elderly housing and the parish. The main pipe network is made up of traditional double district heating pipes of steel with polyurethane insulation and a polythene casing.

The financial results have improved during 2009, mostly due to greatly reduced depreciations. For 2009 the result was +304 000 SEK. (2008: -146 000 SEK) The heat density of the system in Ullared is, being a small scale district heating system, quite normal with a linear heat density of about 0,8 MWh/m. But the key problem of the district heating system in Ullared is the very low connection rate which is roughly estimated to 22%. This is for the system in Ullared at the same time a well needed future potential for expansion. The Environmental impact is important for many customers when they chose their heating system and it is usually a good argument for the district heating industry as a whole. However, the environmental impact from low density district heating systems is higher than for traditional systems since both heat losses and resource depletion from pipes and components increase with lower heat density. Still research report referred to in this report states that the choice of district heating is a good choice for the environmental impact for those property owners who today uses fossil fuel for heating. One estimation says roughly a reduction of 40 tons of CO_2-equivalents per year compared with oil furnace heating. Finally, the small scale district heating system in Ullared has definitely the potential of attracting more customers in the future with a well spread out distribution net with many buildings close situated offering an alternative for change of heating system for potential customers for a future connection when energy prices for oil and electricity increases even more. Anyway it will have a positive impact on the environment both globally and locally.

Content

1. Introduction

This evaluation and final report is part of the EU-project, "Energy in Minds" (EiM). The project is a part of the EU-initiative Concerto within the Sixth Framework Programme. EiM has been running from 2005 and is now finalized in May 2010. Within the EiM project, the local energy company, Falkenberg Energi AB (FEAB), has received funding with the following objectives to develop the district heating system within the municipality of Falkenberg [8]:

1.Replacing fossil fuels used for heating with district heating system fuelled with Renewable Energy Sources (RES, wood chips) in the town of Falkenberg. This was achieved by connecting new customers and increasing the heat production and efficiency of existing wood chips boilers.

2.Two new small scale district heating systems using bio energy. One completely new in the community of Ullared and one rebuilt and extended in Vessigebro. The total received amount of EU-funding for the Ullared project is about 56 700 Euro and for the project in Vessigebro about 41 500 Euro. [7]

1.1 Evaluation focus

This evaluation and report is from here on only handling the new small scale district heating system in Ullared. This because it is a completely new system built within the EiM project and therefore it is rather well documented both during construction phase and during operational phase. The report will describe the system and analyse the overall economy for the years 2007-2009. We will also look at total supplied energy to customers 2007-2009 and efficiency with focus on distribution costs. Environmental impacts will also be discussed with focus on reduction of CO_2-emmisions. Finally alternative laying techniques for pipelines, with smaller investment costs, will be discussed.

1.2 Method

Data received from FEAB [1] [2] about the geography of the system as well as figures of used and supplied energy for the years 2007-2009 will be analyzed and consolidated. Total used energy and supplied energy will be analyzed for the year 2007-2009. Results will be presented as diagrams and tables. A comparison with average economical key-figures from 36 different Swedish projects of small district heating systems between 1996 and 2003 will be done. (Evaluated in the Swedish research programme for "Sparse district heating systems, 2002-2006")

2. Description of district heating system in Ullared

2.1 Location

Source: Falkenbergs Kommun och Lantmäteriet

Figure 1. Municipal map of Falkenberg with Ullared and Vessigebro.

The small district heating system is situated in Ullared which is a small community about 30 km north-east from Falkenberg. (See map above). Ullared has about 800 habitants with a health-care center, a home for aged people and a school with primary- to secondary grade. The community has a mix of both private houses and smaller residential houses. Ullared is despite its relative small size a large trade center in Sweden dominated by the low price store GeKås. Around the GeKås store many other smaller stores have been established in the center of Ullared. GeKås and Ullared attracts many visitors every year. It is in fact one the biggest tourist attractions in Sweden.

2.2 Boiler and heat production

The heating plant is prefabricated and transportable. It is placed at the school in Ullared. (See map in Figure 4 below). The boiler has the power of 1500kW and is fuelled with wood pellets. As reserve plant are two older oil boilers of 340 and 440 kW, in the school used.

Figure 2. New main boiler of 1500kW fuelled with pellets (Stepfire by TPS).
Source: FEAB [2].

Figure 3. New district heating plant in Ullared.
Source: FEAB [2]

The heating plant has a fuel-storage of 80m^3 pellets. The main boiler works with a system temperature of 90/55 C. The efficiency of the main boiler is according to FEAB about 83%.

Table 1. Predicted fuel use, energy conversion and energy use by customers.

Fuel use Pellets and oil	Hot Water production	Customers use	Customer heat demand
2533 MWh	2106 MWh	1902 MWh	1169 kW
Efficiency, HWP 83%			
Energy losses in distribution network 10%			

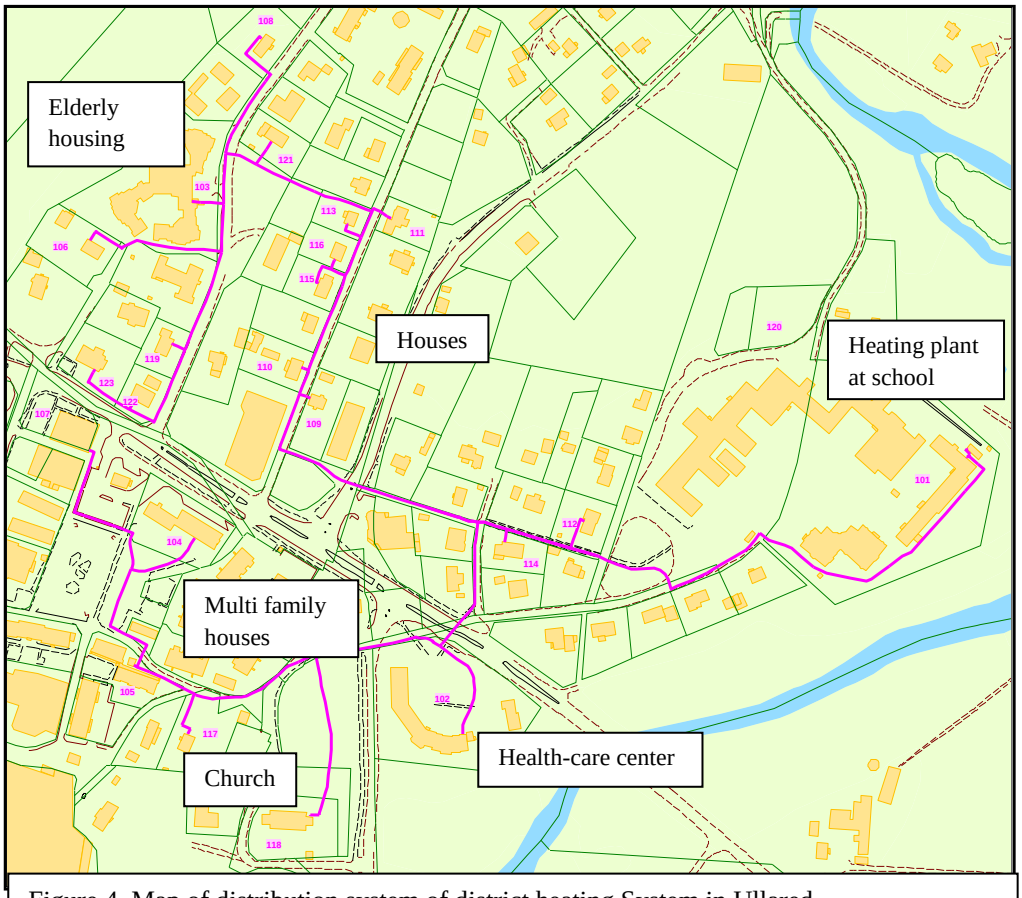

Figure 4. Map of distribution system of district heating System in Ullared.
Source: FEAB [2]

2.3 Distribution system

The distribution net can be seen in the map above (Figure 4). The construction of the net is seen in the section below. The total length of the pipe network is right now about 2476 meter. The pipe type used is Twin/double pipe manufactured py Power Pipe of steel with polyurethane insulation. (See also Table 2:)

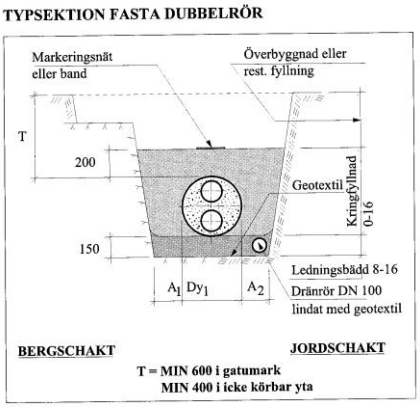

Figure 5. Section through pipe trench in Ullared.
Source: FEAB [2]

Table 2. Expansion of the distribution net with pipe dimensions (in mm) and total lengths (in m).

Expansion of Distribution net	Ser-vice-pipes	DN 25	DN 32	DN 40	DN 50	DN 65	DN 80	Total
Construction 2006	15	309	0	72	1032	539	0	1956
Construction 2007	7	260	0	0	256	0	8	524
Construction 2010*	1	48	120	0	12	0	0	180
Total	**23**	**617**	**120**	**72**	**1300**	**539**	**8**	**2656**
Water volume (in litres)		723	228	216	5975	4204	85	11431

*Construction work will start in August 2010 with connection of sports hall. (Heat demand is 100 kW)

All expansions have been done with pipes from Power Pipe with extra polyurethane insulation. This means that the pipes outer mantle have extra large diameter compared with standard pipes. The net is built for 16 bars pressure with a maximum temperature of 110°C. The average inside pipe diameter of the network is 47mm. Table 3 below shows the heat transmission capacity of the pipes at a temperature difference at 50°C (=Δ T**)** and the heat losses per meter pipe at an outdoor temperature at +5°C and an average temperature of the water in the pipe of 70°C. (ΔT=65°C). (Ref. Power Pipe)

Table 3. Technical specifications of pipes. Source: Power Pipe [9].

Nominal diameter DN	Outer diameter and thickness Steel tube Dy x s (mm)	Outer di-ameter of pipe mantle Dy (mm)	Weight kg/m	Distance tubes (mm)	Flow (m/s)	Transm. Capacity At Δ**T=50**°C (kW)	Heat losses At ΔT=65°C (outer temp +5°C) (kWh/m, yr)
20	26,9x2,0	160	6,7	19	0,8	65	78
25	33,7x2,3	160	7,7	19	0,8	100	97
32	42,4x2,6	180	9,8	19	0,8	180	107
40	48,3x2,6	180	10,4	19	0,9	230	125
50	60,3x2,9	225	14,3	20	0,9	370	121
65	79,1x2,9	250	17,9	20	1,0	700	143
80	88,9x3,2	280	22,9	25	1,0	1000	156

2.4 Customers and heat demand

The district heating system in Ullared replaces mainly individual boilers using fossil oil by the customers. The system has for the moment 22 customers, which nine are one family household (houses), one is the school building where the heating plant also is located, a couple of multi-family houses, one health care center and one elderly housing. The total heat demand is 1169 kW. As mentioned above a new sports hall, currently under construction will be connected with a further heat demand of about 100 kW. The construction of the sports hall is expected to be finished by the year change 2010-2011. The potential of connecting more customers looks good, at least when looking at the system map above. (Figure 4). More about the connection rate and the conclusions around that will be analyzed and discussed later in this report.

3. Energy conversion 2007-2009

Table 4. Facts about the energy conversion and the distribution net in Ullared.

Energy conversion and linear heat density for 2007-2009	Outcome 2007	Outcome 2008	Outcome 2009
Purchased fuel (oil & pellets, MWh)	2449,7	2532,9	2885,1
Conversion losses (MWh)	818,6	426,7	610,1
Conversion losses (%)	33,4	16,8	21,1
Conversion in heat plant (MWh)	1631,1	2106,2	2275,0
Total heat loss in distr. net (MWh)	67,1	204,2	322,0
Total heat loss in distr. net (%)	4,1	9,7	14,2
Delivered to customer (MWH)	1564,0	1902,0	1953,0
Total pipeline length (m)	1 956	2 476	2 476
Linear heat density (MWh/m) [3]	0,80	0,77	0,79
Flow (m^3/year)	56352	44787	54890
Connected customers	19	22	22
Estimated connection rate	22%	26%	26%
Pipeline length/connected customer	103	112	112

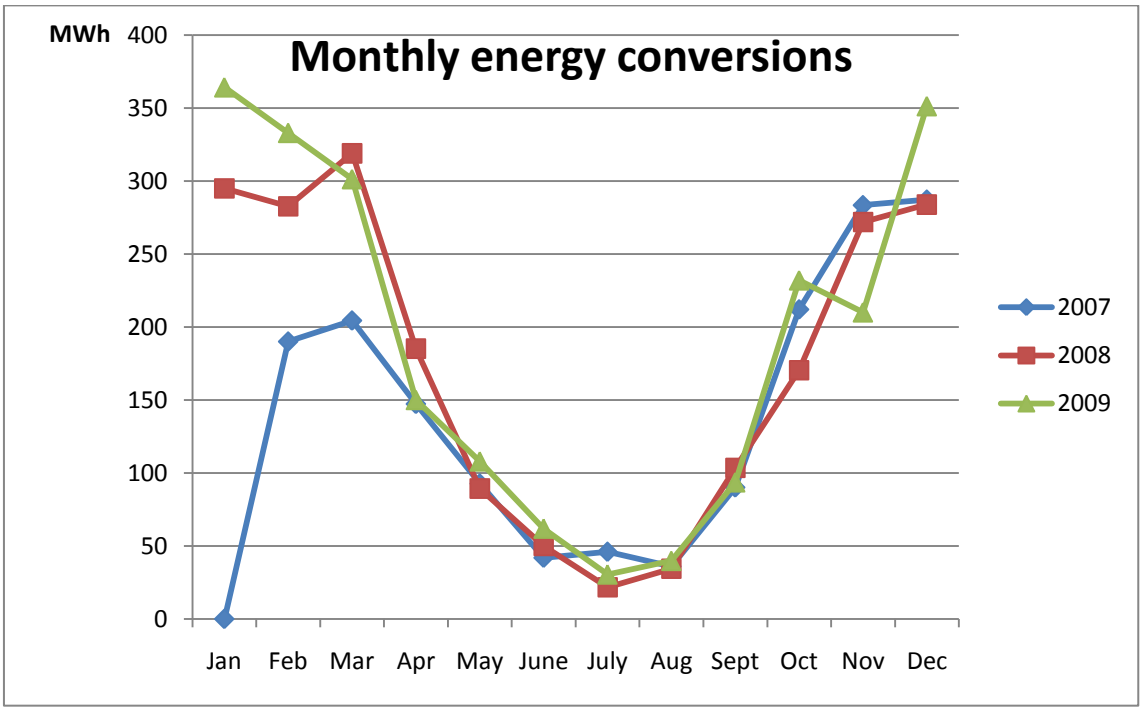

Figure 6. Outcome of converted energy/month by the heating plant in Ullared during 2007-2009. Note that the first metered figures are from February 2007 when the new heating plant became operational.

4. Economy

4.1 Investments

The investment cost in the district heating system in Ullared specified for Heat plant and Distribution network.

-Heat plant including boiler: 474 700 Euro (about 4.7 million SEK)

-Distribution network: 664 100 Euro. (about 6.6 million SEK)

Total investment; 1 138 800 Euro (about 11.4 million SEK)

The investment cost above is the initial investment cost for the first construction phase, 2006. The average total investment cost per connected customer is 59 940 Euro. (about 600 000 SEK) (calculated with 19 connected customers).
The average investment cost/meter of the distribution pipes is: 582 Euro/m (about 5800 SEK/m). See more in Table 6 below.

4.2 Operational economy 2007-2009

The operational economy of the two first years of operation 2007-2008, has been strained. This is mainly because of high depreciation costs due to the relative high investment costs. FEAB's forecast for 2009 (See Table 5) stated a much smaller depreciation compared with earlier years. If this is true for 2009 the result for 2009 will be positive with +550 000 SEK.

Table 5. Income statement with outcome for the years 2007-2009 and with a forecast for 2010.
Source: FEAB [1]

Economy 2007-2009	**Outcome**	**Outcome**	**Forecast**	**Outcome**	**Forecast**
	2007	**2008**	**2009**	**2009**	**2010**
Supplied and sold energy (kWh)	1 564 000	1 902 000	1 912 609	1 953 000	*1 925 862*
Revenue (sales price in SEK/kWh)	0,81	0,82	*0,87*	0,86	*0,87*
Total revenue (SEK)	1 266 963	1 558 154	1 663 970	1 671 011	1 675 500
Fuel cost (SEK)	-898 528	-802 379	-898 360	-972 884	-1 009 780
Operational cost (SEK)	-345 006	-340 528	-231 726	-294 057	-378 610
Depreciations (SEK)	-307 819	-423 819	-57 440	-42 402	-67 440
Interest (SEK)	-88 999	-137 813	-57 480	-57 480	-78 439
Total costs (SEK)	-1 640 352	-1 704 539	-1 245 006	-1 366 823	-1 534 269
Results (SEK)	**-373 389**	**-146 385**	**418 964**	**304 188**	**141 231**
Profit margin (%)	-29%	-9%	25%	18%	8%

The financial results are slowly improving, as it seems mainly because of reduced depreciation costs from 2009.

5. Results

5.1 Financial Results

The financial result has according to FEAB's statements improved for the year 2009 to a plus result of about 304 000 SEK which is of course much better compared with earlier years. But to be truly profitable the system in Ullared needs to increase the total heat demand quite much.
The district heating system in Ullared has some factors that make it difficult to become a profitable and effective investment. As mentioned in chapter 4.1 above, the investment cost per connected customer is high and also the investment cost per meter of pipe is relative high. A problem with the system in Ullared is also the low connection rate with now only 22 connected customers. Therefore the system is very sparse with many meters of pipeline/connected customer. See more in chapter 6.1 below. When also the linear heat density of the system is relative low (see Table 4), at least compared with normal district heating systems, it also has a relative high cost of distribution per delivered energy unit.

5.2 Environmental results

The Environmental impact is important for many customers when they chose their heating system and it is usually a good argument for the district heating industry as a whole. However, the environmental impact from low density district heating systems is higher than for traditional systems since both heat losses and resource depletion from pipes and components increase with lower heat density. A report in this context is made by M. Fröling [4] studying the environmental limitations of sparse district heating when installed as a replacement for local oil furnace-heating. This is also a main objective for the "Energy in Minds" projects and the Ullared project in particular. Fröling created a model comparing the space heating of a single family home with an oil furnace or with district heating. The model uses the factor, linear heat density, to give a general idea of the environmental limit for low heat density district heating systems. The assessment made by Fröling is "that with the type of technology used at present it is not environmentally beneficial to use district heating with lower linear heat density than 0,2 MWh/m. At higher linear heat densities Swedish average district heating production is the environmentally better choice, when compared to a local oil furnace for a single family home with an annual heat demand of 20 MWh". As presented in Table 4 earlier, the heat density for Ullared is almost 0,8 MWh/m which according to Fröling's model should make the district heating a good choice for those property owners who today uses fossil fuel for heating.

When looking at the global warming impact and reduced CO_2-emissions from the district heating system in Ullared it is calculated by FEAB to reduce the CO_2-emissions from 560 tons/year from replaced oil furnaces to less than 60 tons CO_2 per year. Thus, an annual reduction of 500 tons of carbon dioxide per year. Comparing with Fröling again, using the heat density for Ullared (0,8 MWh/m) in the diagram below, made with his model, it says roughly a reduction of 1,8 tons of CO_2-equivalents per year and connected house. The connected house is in the model of Fröling, as mentioned above, a single family home with an annual heat demand of 20 MWh. To make it simple, we assume 22 of these type houses in a estimation of CO_2-reductions for Ullared. This results in an annual reduction of about 40 tons CO_2-equivalents.The figure of CO_2-reduction according to Fröling is probably closer to the truth as this model is based on life cycle inventories for district heating systems specially designed for low heat density areas.

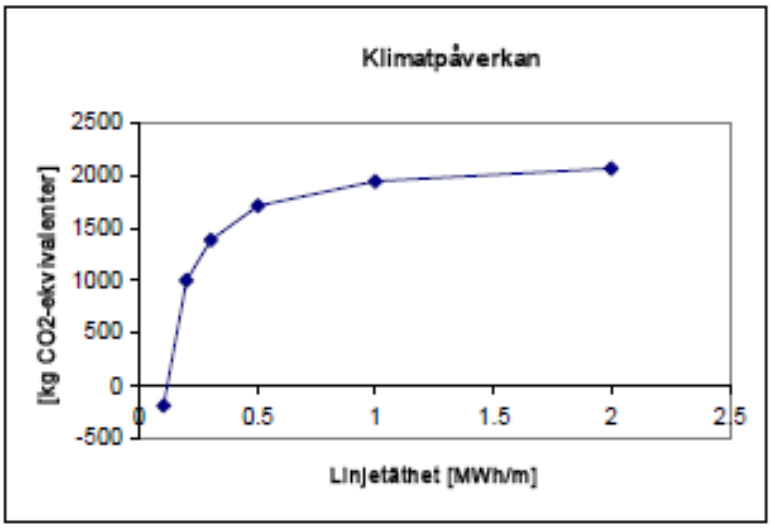

Figure 7. Result from model of Fröling regarding Global Warming Potential. The contribution if using a local oil furnace minus the contribution if using district heating is shown. [4] Vertical axis: kg CO^2-equivalents per house of 20 MWh. Horizontal axis: linear heat density.(MWh)

6. Comparisons, conclusions and solutions

6.1 Comparisons

To evaluate above mentioned factors and the outcome and effectiveness of the small scale district heating system in Ullared a comparison with some of the results from the research Programme "Sparse district-heating in Sweden 2002-2006" is done. [6]. The research is about low heat density areas, e.g., suburban single family houses and small villages and was initiated by the Swedish District Heating Association.

Table 6. Comparison with some of the results from the research Programme "Sparse district-heating in Sweden". [6] The columns "Present 2006" represents average values from 36 projects with connection of family houses to district heating between 1996 and 2003. The column "Goal Sparse DH" represents values when the goals of the research program are met.

Input	Ullared 2008	Present 2006	Goals Sparse DH
Heat delivery /house MWh	100	22,8	20,0
Connection rate %	22*	69	70
Linear heat density MWh/m	0,77	0,58	0,7
Connection costs (in SEK)			
Cost of heating plant/connected house	237000	33518	16781
Pipeline cost/connected house	332000	65332	36000
Other costs/connected house	0	5153	5153
Total cost/connected house:	**569000**	**104003**	**57934**
Average cost/m pipeline	5527	1424	742
Total pipeline length/connected house	103	39,2	28,6

*The connection rate for Ullared is very roughly estimated, from the system map in Figure 4, by the author of this report.

6.2 Conclusions

When analyzing the figures in the Table 6 above some interesting conclusions can be made:
-The heat delivery per connected house/customer is about 5 times bigger compared with the "Goals Sparse DH". Probably because the "Goals Sparse DH" is based on connection of mainly family houses and in Ullared there are only about nine connected family houses of total 22 connected houses. The other 13 houses are residential or municipal houses with a bigger energy demand. This is obviously not the problem for the district heating system in Ullared.

-The main problem, but also great potential for growth and improvement of efficiency for the system in Ullared is the low connection rate, 22% compared with the "Goals Sparse DH" at 70%. The low connection rate means that the total pipeline length per connected house or customer is about 3-4 times higher than the referred research program says. This is the key problem for the system in Ullared which is also seen as a very high investment cost (569 000 SEK) per connected house which is almost ten times more than in the above referred "Goals Sparse DH".

-Not only is the connection rate low for Ullared, the chosen pipeline technology in tradition from large scale high density district heating (steel tubes with polyurethane insulation) means very high average investment cost per meter of pipeline compared with the "Goals Sparse DH" and the relative low Heat Density of the system. This conclusion is also made in the report "Sparse district-heating in Sweden"[6], which says: "Tradition from large scale high-density

district heating is hard to scale to fit sparse district-heating systems". This aims at the pipeline technology as well as working routines, customer communications, like in sales and marketing, prior to the construction work itself. Maybe more efforts could have been made in these early phases with information and marketing etc in the Ullared project.

6.3 Possible Solutions and alternatives

The report "Sparse district-heating in Sweden"[6] presents some interesting alternatives for district heating distribution in low heat density areas.
-One is a technological improvement with the potential to reduce the investments costs for the pipeline, is to reduce the laying depth. "The current requirements on laying depth for pipes in road structures have been shown to be unnecessarily strict for small pipes in roads with moderately heavy traffic".[10]. This knowledge could very well be used for eventual further expansion of the system in Ullared as well as in other small district heating systems or for expansion in low heat density areas for existing district heating systems.

-Another alternative, which is perhaps preferable, for use in completely new district heating systems is the so called "Finnova system" which is a new concept optimised specially with the demands of sparse district heating in mind. The Finnova system was one of the most successful demonstration-projects in the research program of "Sparse district-heating in Sweden"[11]. See Figure 8 below.

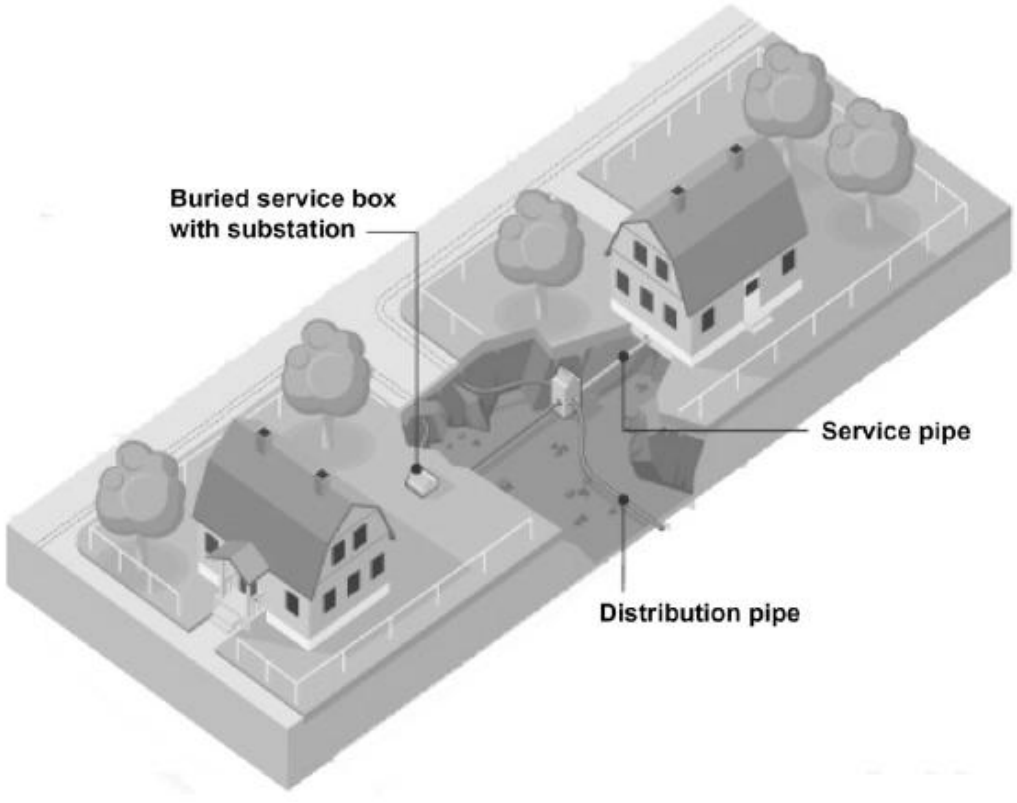

Figure 8. The Finnova system suggested as an innovative solution for district-heating distribution. It is based on joint-less flexible pipelines connecting underground sub-stations placed in cabinets buried at the plot boundary. Source [6], [11]

When comparing some key factors from the demonstration project of the Finnova-system with the system in Ullared and the Goal of sparse district heating referred to earlier, we can see following:

Key figures	**Finnova**	**Ullared**	**Goal Sparse DH**
Pipeline length/house (m)	41	112	28,6
Pipeline cost/house (Euro)	4 000	30 000	3 800

The figures give a picture of the big difference in the investment cost for the distribution net using traditional laying technology and methods from large-scale district heating on a small scale or sparse district heating system (as in Ullared), compared with a new innovative district heating technology. The new laying technologies were probably not available, at least not so well proven as now, when the district heating system in Ullared was planned. But for future expansion of Ullared or for new potential small scale district heating systems, new technologies like the Finnova-system can make district heating financial profitable also in low heat density areas and small villages. One can perhaps also expect that the new district heating technologies will have even better possibilities in reducing environmental impact when connecting new customers converting from fossil fuel or electricity heating.

The final conclusion is that it needs new thinking in many aspects to build a profitable and efficient small scale district system such as Ullared. Aspects which could have impact of the result are according to the conclusions in the report "Sparse district-heating in Sweden"[6] :
-A revised way of customer communication for attracting more customers resulting in a better connection rate.
-More efficient working routines during construction.
-An innovative new pipeline technology with reduced investment costs.

Considering the district heating system in Ullared as it is now, constructed and with the connected customers, the solution is, on the paper, very simple: Invest in good marketing and information to potential customers to be able to connect more customers with substantial heat demand situated close to the existing pipeline. This will improve the effectiveness of both the heating plant and the distribution net. If possible connect the new customers with a less cost-intensive pipeline technology as described above. For example, there are still some multi-family buildings not connected, in the village situated very close to the pipeline. This is of course an option already considered by FEAB.

To sum up, the small scale district heating system in Ullared has definitely the potential of attracting more customers in the future with a well spread out distribution net with many buildings close situated offering an alternative for change of heating system for potential customers for a future connection when energy prices for oil and electricity increases even more. Anyhow it will continue to have a positive impact on the environment both globally and locally.

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