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Environmental performance of district heating in suburban areas compared with heat pump and pellets furnace

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ABSTRACT

District heating networks are increasingly expanded into suburban areas with single family houses, e.g. to utilize heat from combined heat and power generation. The economics of each district heating project normally decides if a specific network will be constructed, but there is also an environmental dimension in the decision-making. For customers in the situation to decide if to connect to district heating, environmental friendliness is often a complimentary argument, beside economics.

When expanding district heating distributions systems into areas with lower heat density, the economic cost for using district heating will increase compared to more densely build areas. At the same time the environmental impacts from the district heating system will increase; construction of more pipes, excavation of longer pipe trenches, increased heat losses will all contribute to this.

This study investigates the environmental limitations for use of district heating in areas with low heat density. Life cycle methodology is used to model and compare the environmental impacts from the heating of a single family house (20 MWh/year) by a local heat pump or pellets furnace or by district heating, using different fuel mix for district heating and varying the linear heat density of the district heating distribution system. Comparison with a local oil furnace has been presented in a previous study.

Environmental impacts has been characterized and compared as contributions to global warming, acidification, and use of finite resources. This study does not regard the economy of the use of district heating.

The outcome of the comparison is highly dependent on type of electricity generation and fuel mix for district heat generation.

1. INTRODUCTION

District heating networks increasingly are expanding into areas with single family houses, in Sweden as well as other countries [1, 2]. Beside economics, environmental friendliness is often a complimentary argument for customers in the situation to decide if they want to connect to district heating.

When expanding district heating distributions systems into suburban areas (lower heat density) the economic cost of district heating will increase compared to more densely built areas. At the same time the environmental impacts from the district heating system will increase; construction of more pipes, excavation of longer pipe trenches, and increased heat losses will all contribute to this. At the 9th International Symposium on District Heating and Cooling we presented a study we presented a study of the environmental balance (using Life Cycle Assessment) between use of district heating and a local oil furnace at different linear heat densities for the district heating system [3]. The comparison was made with the fuel mix of average Swedish district heat generation. In this study we compare the heating of a single family house (20 MWh/year) using district heating (varying linear heat density and three fuel mix scenarios: natural gas CHP, biofueled boiler using wood chips and Swedish average mix) with a local furnace using bio fuel (wood pellets) and with the use of a heat pump (two electricity scenarios: coal power and natural gas combined heat and power). The full life cycle inventory is available in Swedish [4].

The district heating pipes studied are PUR-insulated steel pipes of twin type. The model used to describe the life cycle environmental consequences of a district heating network with low heat density is described in earlier study [3]. The model draws on extensive work studying the environmental performance of district heating pipes [5,6,7,8].

2. COMPARING DISTRICT HEATING WITH OTHER HEATING

The district heating network has been studied for different linear heat densities (the heat delivered by a given district heating system during one year divided by the pipe length of the system). The network serves a standard single family house with a heat need of 20 MWh/year. In reality, a district heating network is of course more complex and differs by other means than just linear heat density and generally serves several types of buildings. Here the model has been simplified to illustrate general trends. To obtain exact information on environmental performance of a specific network this specific network should be studied.

2.1 Overall Model

In this model general data has been used with the linear heat density of the distribution system as varying parameter. For a given linear heat density the model sums up the environmental impacts from construction of the resulting length of pipe network (including a district heating central in each house as well as the impact from constructing production facility) with the impact from generating heat to cover the heat losses from the same network and to generate the delivered heat to a single family house with a heat need of 20 MWh/year. The environmental impact from building a pellet furnace and production and delivery of wood biofuel pellets needed for heating the same house is summed up in the same way. Building and installing a geothermal heat pump (including drilling) is studied in the same way together with generating the electricity to run it. Two scenarios were studied, coal power and natural gas combined heat and power (CHP). The results for these three alternatives is characterized into Global Warming Potential [9], Acidification [9], and Finite Resource Use [10].

The different life cycle models are described briefly below. A full description of the life cycle inventories is available in Swedish [4].

2.2 District Heat Distribution System

The district heating pipe system has been considered to be built with DN32 twin pipes (see [3] for details). The pipe dimension describes the average of both main and service pipes in the low heat density area. For the environmental impact from the pipe production, data is adapted from [5,6,8]. For the environmental impact from the laying of pipes, data is adapted from [7,8], with the largest difference that a shallower pipe trench has been used than what is described by the laying instructions from the Swedish District Heating Association (630 mm cfrd to 950 mm, see [3] for details). The impacts from constructing the pipe network are allocated over a time period of 30 years. In this study impacts from constructing the production facility has been added using amounts of building materials used from three Swedish plants [4]. The heat losses from the DN32 twin pipe system was calculated according to [11], taking into account the slow deterioration over time of the insulating capacity.

2.3 District Heat generation

The environmental impact from district heating production for delivered heat and heat losses from the pipe network is described using two scenarios:

- Biofueled boiler. Environmental impacts from production and transports of fuels and from combustion of fuels (with flue gas condensation and flue gas cleaning according to he average Swedish situation) are included [12].
- Natural gas combined heat and power. Environmental impacts from production and transports of fuels and from combustion of fuels are included [12]. The allocation between electricity and heat is based on how much fuel it should take to generate the same amounts of electricity and heat in separate plants.

2.4 Pellets Furnace Heating System

Data regarding the amount of materials in a pellet furnace has been studied as a furnace from NIBE [13]. A wooden pellet store is also included. The weigh of the furnace is 150 kg and its service life assumed to be 20 years. Life cycle inventory data from the production of included materials has been taken into account [14,15,16] but not from the manufacturing of the furnace. Environmental impacts from production of wood pellets and from combustion of the pellets in the furnace are included [12]; the transport of the pellets from the production facility to the house was assumed to 150 km.

2.5 Geothermal Heat Pump Heating System

Data regarding the production and installation of a geothermal heat pump has been studied as a Greenline C7 IVT [17]. The weigh of the furnace is 235 kg. Life cycle inventory data from the production of the heat pump, generation of included materials and regarding the installation of the heat pump (including drilling) has been taken into account [4]. The service life of the heat pump was assumed to 20 years and for the installation in the drilled heat well to 50 years. Electric heating is used for peak load conditions. The annual electricity use considered for the heat pump is 7600 kWh. Environmental impacts from electricity generation are described below.

2.6 Electricity generation

Two scenarios for electricity generation are considered in this study, coal power (in a condensing plant) and natural gas combined heat and power. The environmental impact from coal power generation including coal mining was described by data from [18]. The environmental impact from natural gas combined heat and power electricity was described by data from [12]. The allocation between electricity and heat is based on how much fuel it should take to generate the same amounts of electricity and heat in separate plants.

3. RESULTS AND DISCUSSION

The results characterized as Global Warming Potential (GWP) is shown in Figure 1. District heating with heat from natural gas CHP competes well with a heat pump using electricity from coal power down to a linear heat density just above 0.2 MWH/m, but can not compete with the heat pump if it uses electricity from natural gas CHP. District heating using heat from a biofueled heat only boiler compete well with a heat pump for all investigated linear heat densities regarding both types of electricity used. Disregarding heat type district heat can not compete with a pellets furnace. The most important reason is the need to cover heat losses from the district heat distribution system. Use of better insulated district heating pipes would increase the competitiveness of district heating.

Figure 2 shows the results characterized as Acidification Potential (AP). Eutrophication potential shows a similar trend and is not shown. A heat pump using coal power can not compete with any of the alternatives in this study. There are no large differences between the other alternatives down to a linear heat density just below 1 MWh/m, with the heat pump using electricity from natural gas CHP as the slightly better alternative. Below a linear heat density of 0.5 MWh/m district heating performs significantly worse compared to the other two alternatives in the lower AP region. Different options to further reduce NOx emissions in district heat generation should be considered. Increased long term insulation capacity of the district heating system would again increase the competitiveness of district heating.

A heat pump using coal power is the worst of the investigated options regarding use of finite resources, see Figure 3. District heat from natural gas CHP gives similar results as a heat pump using electricity from natural gas CHP down to a linear heat density of around 0.7 MWh/m, and then deviates. If the district heat is produced in a biofueled boiler it competes well with the heat pump to below 0.2 MWh/m, but is never better compared to a local pellet furnace.

There are many other considerations for choice of heating that should be taken into account. E.g. use of pelleted biofuel in local furnaces in each house comes out very beneficially regarding the parameters in this study, but regarding larger towns and cities the amount of heavy truck transports into the local streets of heavily populated areas would probably be unacceptable.

The possibility for district heat to use waste heat has not been included in this study, but use of e.g. industrial surplus heat would come out beneficially in regarding the parameters in this study. Better insulated pipe systems for district heat distribution are important for the environmental competitiveness of all use of district heat, especially in suburban areas with single family houses and low heat density.

An additional discussion of how different parts of the technical systems generate the total environmental impact is given in the full inventory report [4].

4. CONCLUSIONS

District heat in suburban areas with low heat density can compete with heat pumps using coal power down to linear heat density of around 0.3 MWh/m. To compete with heat pumps using electricity from natural gas combined heat and power regarding the environmental parameters in this study district heat needs to be produced from bio fuels (or waste heat), the distribution system well insulated and the linear heat density above around 0.5 MWh/m. Regarding local furnaces using pelleted bio fuels district heat can not compete regarding the parameters in this study. However, other considerations, e.g. avoiding large amounts of heavy transports in local streets, may anyway hinder use of local biofueled furnaces in cities. The environmental competitiveness of district heating compared to local oil furnaces down to a linear heat density of 0.3 MWh/h has been reported in an earlier study.

Low heat loss from the distribution system is very important. Here, the use of conventional twin pipes has been considered. Better insulated twin pipes or other types of distribution systems with lower heat losses could give better environmental performance when using district heating in areas with low heat density. Eutrophication and acidification - and all emissions contributing to theses environmental problems – should be given special attention in all use of district heating.

Note that this is a model study, where the model has been simplified to illustrate general trends. To obtain exact information on environmental performance of a specific network this specific network should be studied.

5. ACKNOWLEDGEMENT

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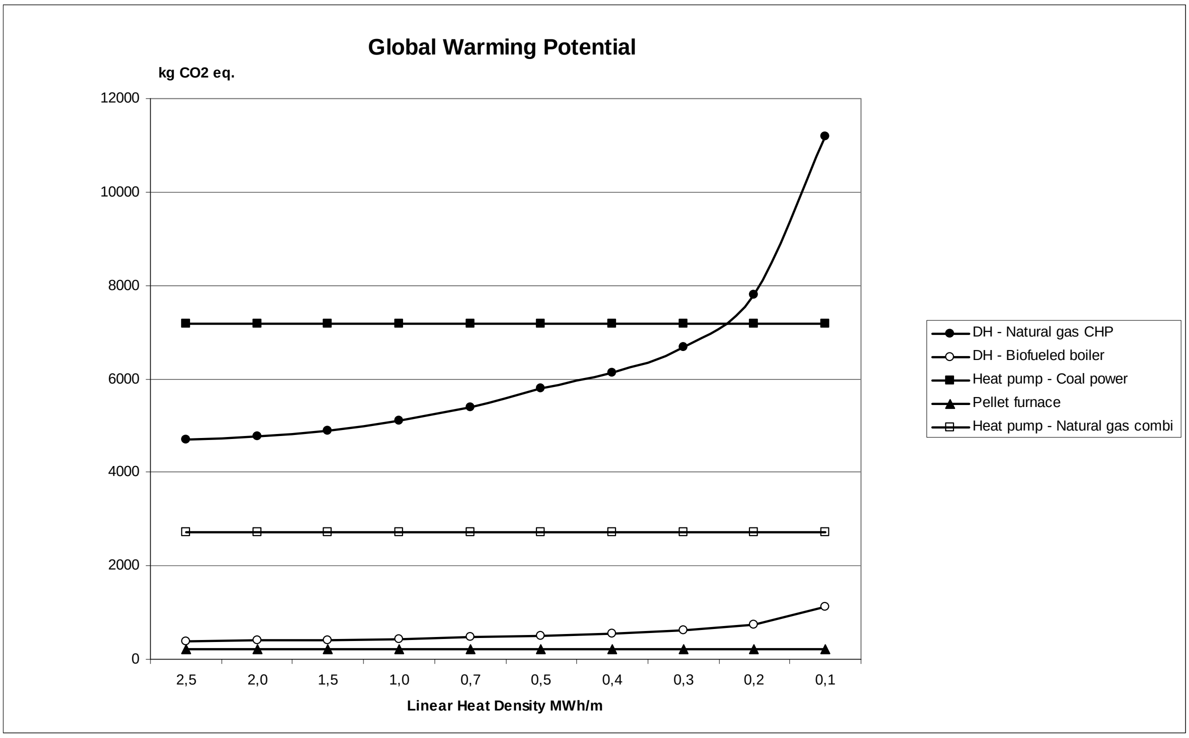

Figure 1. Global warming potential for different heating options for a 20 MWh/year single family house in a suburban area. Varying linear heat density for the district heat distribution system and two types of district heat generation, natural gas combined heat and power and biofueled heat only boiler. District heat is compared to heating with a local geothermal heat pump using electricity from either a coal power plant or natural gas combi plant and with a local pellets furnace.

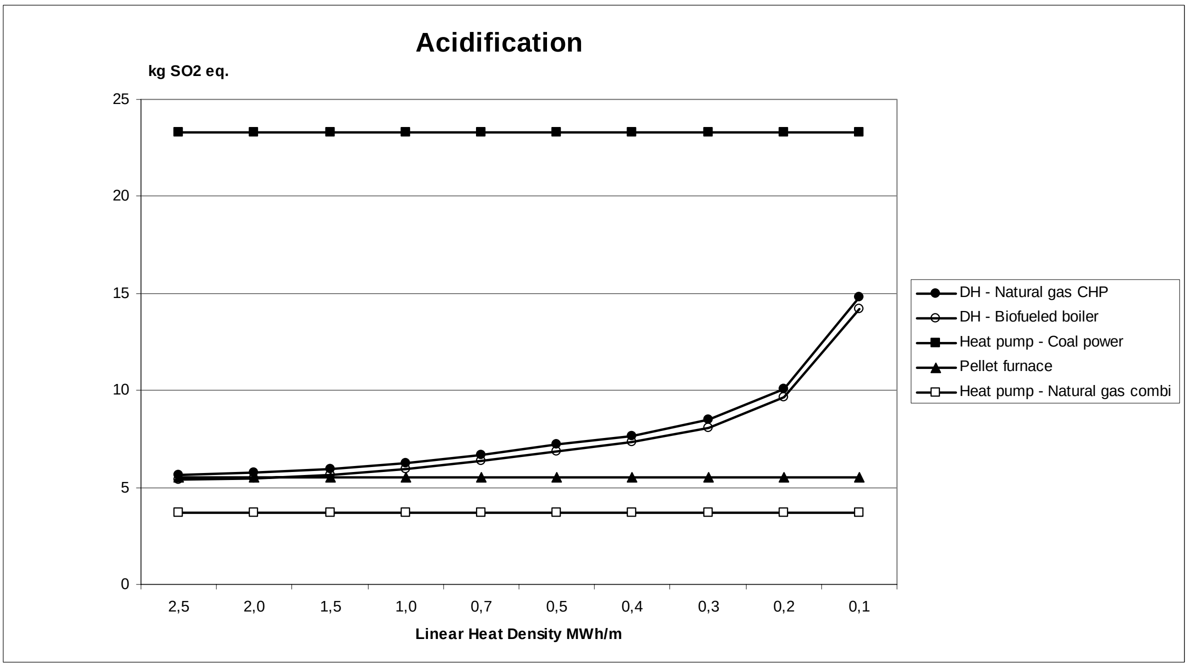

Figure 2. Acidification potential for different heating options for a 20 MWh/year single family house in a suburban area. Varying linear heat density for the district heat distribution system and two types of district heat generation, natural gas combined heat and power and biofueled heat only boiler. District heat is compared to heating with a local geothermal heat pump using electricity from either a coal power plant or natural gas combi plant and with a local pellets furnace.

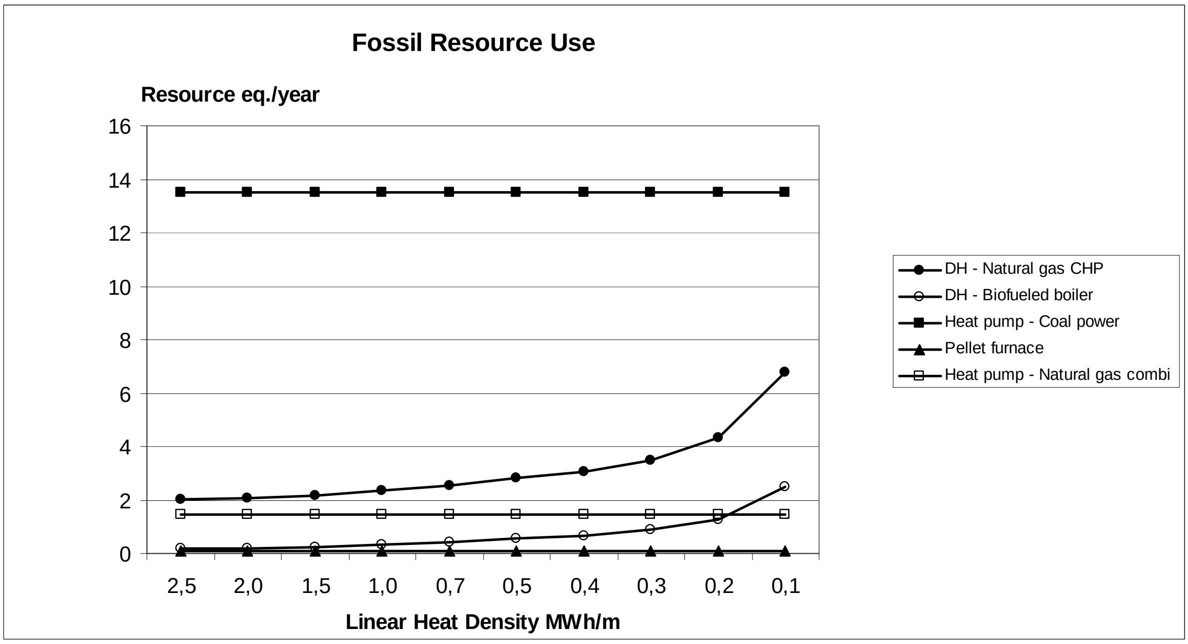

Figure 3. Use of fossil resources (as resource to use equivalents) for different heating options for a 20 MWh/year single family house in a suburban area. Varying linear heat density for the district heat distribution system and two types of district heat generation, natural gas combined heat and power and biofueled heat only boiler. District heat is compared to heating with a local geothermal heat pump using electricity from either a coal power plant or natural gas combi plant and with a local pellets furnace.

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