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District heating (DH) in areas with low heat demand density (HDD): A chance for the integration of renewable energy sources (RES)

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1 Introduction

In the last two decades environmental problems that are caused by utilization of fossil fuels have become more and more the centre of discussion. One consequence of this debate has lead to a search for systems that decrease the amount of fossil fuels that are used for heating. An accelerated development of technologies that use renewable energy sources (RES) such as biogas, biomass or solar radiation for heating has started.

Another technology that can decrease the emission of Greenhouse Gases that are generated as a by-product of heating is district heating (DH).

The major advantages of DH under these aspects are: the possibility of combined heat and power (CHP) generation, the potential for high fuel efficiency and the potential to combine heat sources to provide heat to the customer.

Consequently it is interesting to survey whether DH nets in areas with low heat demand density (HDD) have been established to estimate the potential of this technology. It appears sensible to focus on the question whether the positive effects of a DH system and of providing heat from RES have been combined and what innovative measures have been taken to improve DH net operation.

In a second step it is interesting to investigate what type of heat source is most profitable if current subsidy schemes in Germany are taken into consideration. The results of this research will lay the basics for a guidebook on DH in low HDD areas in Germany.

2 Approach

The goal is to characterize existing rural DH nets qualitatively. This means that the screening of the existing technologies is aimed at giving some information as to what types of small-scale DH nets are already in operation and what their specifications are, especially regarding the integration of RES or potential thereof.

Only a few instructive samples of rural DH nets have been characterized by a survey, to get an impression of the actual development of this sector. In a second step heat generation technologies up to 5 MW are evaluated for their profitability under the precondition of the current German subsidy scheme.

3 Results

DH in areas with low HDD is a technology that is already implemented on a small but growing scale. Especially in Austria small Biomass DH plants have been established, operational for up to 20 years now. The Biomass heating plant technology can be considered quite sophisticated since major problems with this technology have not been arising since 1998 [xiii]. CHP Plants for DH nets with a capacity of approximately 20 MW have been established in Germany [xiv] and Denmark [i]. These examples show that DH in low HDD areas is possible and economically viable if taking the local subsidy schemes into account.

A subsequent data analysis of heat generation costs for Germany has shown that especially RES integrated into CHP processes provide the most profitable way to provide heat for rural DH in Germany. The results of this data analysis are presented under chapter 3.2.

3.1 Operational DH nets in low HDD areas

An overview on sample heat production units that are already in operation is given in Table 1. Table 2 provides information on the attached existing DH nets.

Table 1: Overview on operational heat production units in small and medium-scale DH systems

Country *(Name of DH Community)*	**Type of Heat Generation Unit**	**Fuel**	**Timeframe of operation**	**Thermal Capacity of Heat Generation Unit (kW)**	**Special Features**
Denmark *(Broager)* [i]	• block heat and power plant	• Natural gas	All year	23.000	(power cogeneration)
Austria *(Seibersdorf)* [ii]	• block heat plant	• Straw from regional production	- (survey in progress)	2.200	Very reliable operation for 20 years
Austria *(Arbesthal)* [iii]	• block heat plant • Individual solarthermal units on the roofs of the customers	• Sunflower seed husks and grain from regional production, wood chips, cocoa shells	Heating period (BHP) All year (solar)	1.500	No fossil reserve furnace (block heat plant consists of 2 biomass furnaces)

Table 2: Overview on DH nets in Low HDD area DH systems.

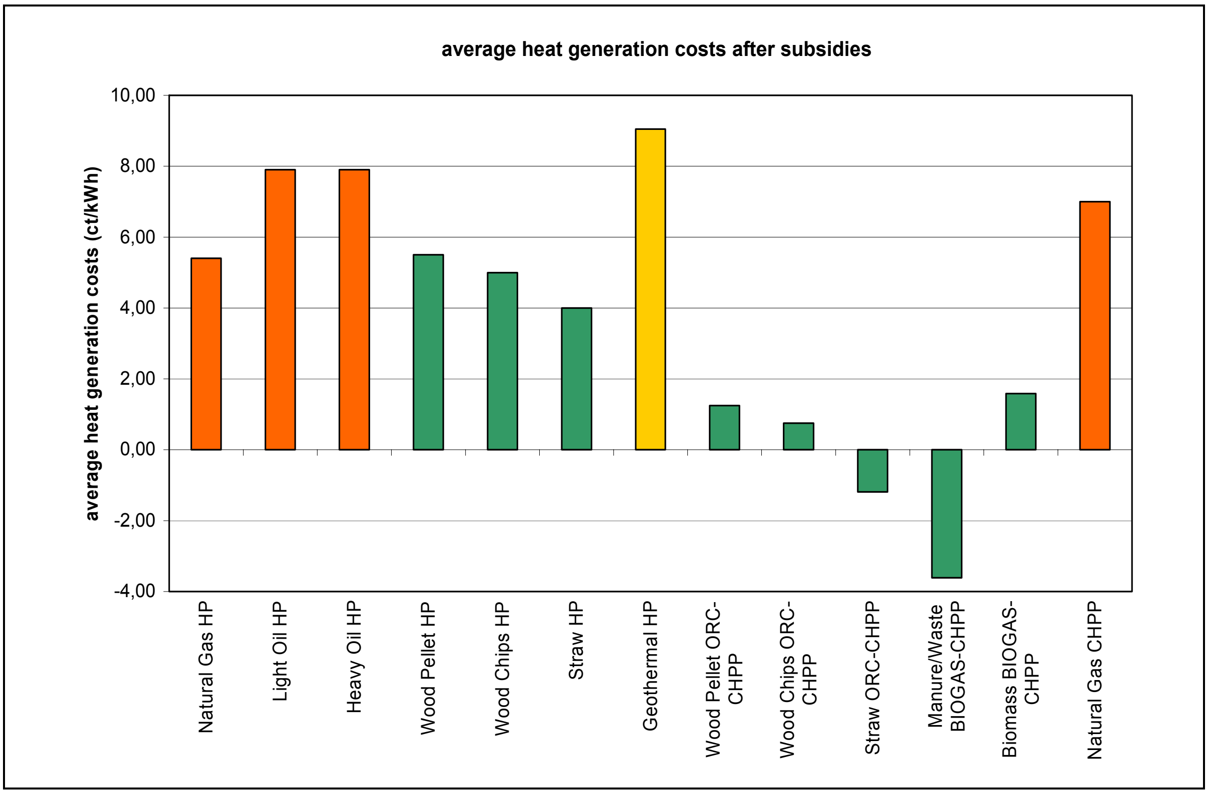
Country *(Name of DH Community)*	**Pipe Material**	**Average Supply line temperature (°C)**	**Average Return Line Temperature (°C)**	**Special Characteristics**
Denmark *(Broager)* [i]	• steel medium pipe (pre-insulated, with plastic jacket)	78	34	1920 m³ hot water tank in DH net allows to switch off block power & heat plant during the night
Austria *(Seibersdorf)* [ii]	• Polybuten-1 medium pipe (pre-insulated, with plastic jacket)	80	65	using only weldable, flexible polymer pipes
Austria *(Arbesthal)* [iii]	• steel medium pipe (pre-insulated, with plastic jacket)	90	70	-

3.2 Comparison of base load heat generation costs for Germany

To asses whether RES are economically attractive as heat generators for rural DH nets a comparison of base load heat generation costs for Germany has been performed. It was assumed that heat generation costs (*German: Wärmegestehungskosten*) given in literature include the annuity for the plant, interest for foreign capital, operation and maintenance costs and fuel costs. The current German subsidies for power from RES have been allocated to these heat generation costs resulting in a decrease of the CHP heat generation costs. The calculation was performed in such a way that it was assumed that the desired product is a given amount of heat. All costs and revenues were allocated to this product. The data used is based on data from various sources and their averages and can only give an evaluation guideline. For a decision in a specific case more accurate data would be needed.

The comparison was aimed at identifying the most profitable heat generators (up to 5 MW) that can be built in a DH net. Heat generators that had comparably high heat generation costs, such as solar thermal panels or CHP with a steam turbine have been taken out of consideration for this reason.

Figure 1: Average heat generation costs in Germany after allocation of subsidies



*HP – Heat Plant, CHPP – Combined Heat and Power Plant

Figure 2: Variation of heat generation costs (Germany) with variation of fuel costs

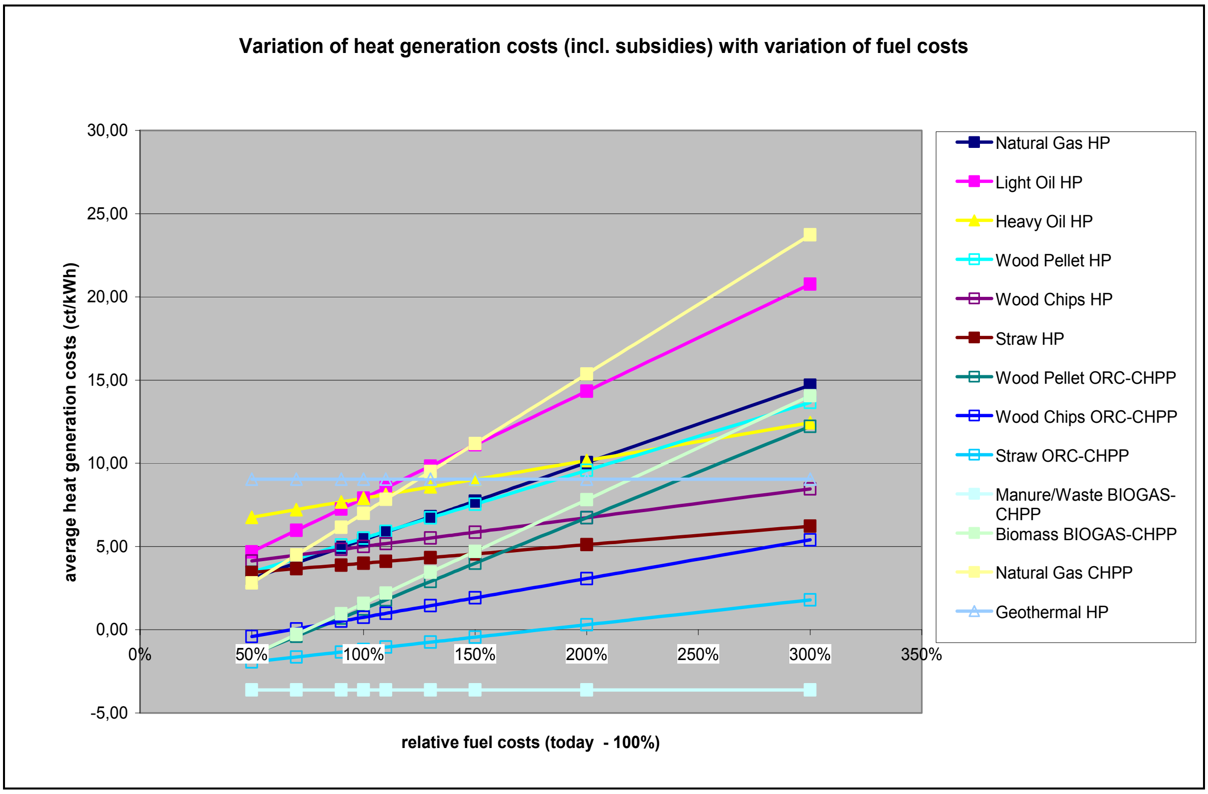


Figure 1 and 2 show that the lowest heat generation costs after subsidies are achieved in Biomass / Biogas CHP plants. The best choice is a manure/ waste Biogas Plant. The free fuel makes this the most attractive heat generator for a DH net in rural Germany. The next best choice is the straw fired Heat Plant with an integrated Organic Rankine Cycle (18 % efficiency). The straw is the cheapest of the non-waste biomass fuels. Combined with the innovative Organic Rankine Cycle, which is basically a steam process with an organic working fluid instead of water it can generate the second highest specific profit. The third best choice is the wood-chip-fired heat plant with an integrated ORC process. Power subsidies result in a lower specific heat generation costs than in any heat-only plant. The different gradient of the curves in Figure 2 results from the fact that heat-only plants need less fuel to generate a given amount of heat than CHP plants.

4 Discussion

4.1 Considerations on Ecological Advantage of DH Nets

The ecological advantage of DH strongly depends on the type of heat source used and on the temperature level at which the system is operated. The first assumption can be easily understood if the alternative between using a fossil fuel heat plant and biomass heat plant is considered. The carbon dioxide neutral heat generation in the biomass heat plant has significant advantages compared to conventional fossil fuel based technology what greenhouse gas emissions are concerned. Especially Biomass / Biogas CHP plants are ecologically attractive, since they use only “waste heat” to provide heat to the customer, while the higher quality portion of the energy that is contained within the fuel is partially used to generate electrical power. Another advantage of centralized DH plants is the better flue gas purification technology compared to “in-house” systems, decreasing the specific emissions of pollutants. This strengthens the recommendation for the use of Biomass in DH – CHP plants instead of burning the fuel in each household individually.

The assumption that the temperature level at which the DH operates influences the ecological benefits of the technology is understood if CHP technology is used to provide the heat. A higher temperature difference allows Rankine Cycles to achieve higher efficiencies. The Organic Rankine Cycle, which is a promising technology in the Biomass DH sector is no exception. Additionally supply line temperatures below 95°C allow the use of polymer medium pipes for distribution. These pipes have a better specific eco balance than steel medium pipes, thus making the DH system more ecologically advanced [v]. Additionally a low temperature can be obtained from a higher number of sources than high temperature heat, such as simple solarthermal collectors, low temperature geothermal sources or waste heat from industrial plants. Including waste heat sources would be another means to save fuel and thus to decrease the pollution caused by heating. Summarizing can be stated that DH nets operating at low supply line temperatures in the combination with RES – CHP plants provide heat in one of the most ecological ways .

4.2 Apparent Trends in DH in Low HDD areas

Especially in Austria RES are very popular for small-scale DH nets. This is largely owed to federal, state and local support for biomass DH Plants which commenced in the 1980s. In 2001 694 biomass DH Plants produced a total of 822 MW heat in Austria [iv]. In Denmark where DH in rural areas has a history of over 40 years, DH nets have a difference of up to 44 °C between supply line temperature and return line temperature. This is to a great part owed to the regulations that Danish DH carriers established. In Broager for example customers signed a contract to deliver 33 °C temperature difference as a yearly average between supply line and return line temperature. The consequence of failing to meet this requirement is an increase in the DH bill by 0.8 % per °C decrease in delivered temperature difference [i].

Several demonstration objects for biomass DH plants have been installed in Germany [vii], confirming the trend to generate heat from biomass on a community scale.
The use of biogas as a fuel for local block heat and power plants which can be connected to a small – scale DH net is increasing in popularity and holds promising potential for small - scale DH nets especially in agricultural areas [xii].
Summarizing it seems that the major RES that is used in low HDD areas for DH systems are biomass or biogas derived from it. Often mentioned advantages include use of regional resources such as agricultural or wood waste utilization and the generation of jobs for local residents. These positive effects and the increasing costs for fossil fuels combined with the support of RES based technology by the respective governments [v] [vii] are the basis for continued growth in the biomass driven DH market. Our calculations on the comparison of heat generation costs for the most popular technologies also confirmed this trend.
A less significant trend is the increase in use of geothermal and solarthermal heat sources for district heating. In regions where hot underground water is comparably easily available, geothermal plants have been installed and connected to DH nets [xi], similarly solarthermal units with long term hot water storage have been installed to provide up to 50 % of the required heat for several buildings [x]. While geothermal plants tend to have a minimum size at which they become economically viable, heat generated by solarthermal plants becomes cheaper as the size of the plant increases [ix][x]. Currently both technologies apply to mostly medium HDD areas. These technologies are thus generally applicable for district heating in low HDD areas but the requirements that need to be met in order to be economically feasible are harder to fulfil. Nevertheless research in these two technologies is in progress expanding their field of application.

5 Conclusion

In various countries small-scale DH nets in low HDD areas nets have been build or taken into an advanced stage of planning [xi]. In many cases heat is generated from RES or in CHP plants. Conducted interviews have returned that the biomass heating technology is mature and reliable and that the operation of small DH nets is generally well tested [i-iii]. Developments are underway to find DH concepts for low HDD areas that are fully competitive on the open heat market. So far it was identified that in Germany Biomass / Biogas – CHP plants are the most economically attractive heat generators for the base heat load in DH nets. Additionally they incorporate a maximum of ecological advantages over fossil heat only plants. Further research will show whether and under which conditions DH becomes an economically viable alternative in German low HDD areas.

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