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Urban Heating

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ABSTRACT

Geothermal heat is perfectly suited for heating buildings in the colder regions of the world. However, the usage of this sustainable and environmentally-friendly resource is limited due to the need of district heating systems. Investments in building of district heating are very costly. Besides the challenge to develop new district heating systems there is also a transformation of energy usage going on in several countries of Europe: coal will no longer be used for power generation. As a side effect, the accompanied heat, traditionally delivered by district heating nets, will no longer be available in the future. Again geothermal heat is perfectly suited for substitution. However, geothermal heat does typically occur with temperatures lower than needed by old district heating systems, which defines another technological challenge.

1 INTRODUCTION

Geothermal energy is since decades used worldwide for heating houses (Sanner et al., 2003, Huenges and Ledru, 2011). Obviously Earth's interior heat is most easily and successfully applicable for heating. In regions with high enthalpy geothermal heat (e.g. Iceland or Tuscany/Italy), power generation is a further strength of geothermal energy. However, so called enhanced/engineered geothermal systems (EGS) in low enthalpy regions still have to prove their general applicability. Generally, the economic feasibility of EGS improves by cogeneration (Huenges and Ledru, 2011).

Obtaining hot water with temperatures suitable for heating from depths of approximately 2000 meters using multiple drillings is - from the point of technology – no longer a substantial challenge. This is shown by several operational geothermal wells, for instance in Germany at Munich Unterhachingen, Landau, Insheim. However, the delivery of the heat to houses seems to be the bigger challenge.

According to AGFW (2013) in Germany 1,337 district heating networks with a total length of 19,650 km exist which supply heat to 322,250 customers. Within the last years the installed load has decreased constantly and has had a value of 148 kW in 2012; in 1999 this value was 174 kW. While 23 % of apartment houses in existing holdings are supplied by district heat the percentage for one or two family houses is only 2 %. For new buildings the portion for one or two family houses is 5 %; for apartment houses it stays stable with 23 %.

In 2011 there were 212 geothermal district heating systems operated in Europe with a total installed capacity of approximately 4,700 MW_{th} (data from GEODH website).

The purpose of this conference contribution is to support the idea of combining low enthalpy geothermal heat with existing or newly developed district heating systems. Several challenges are related with such a concept which will be discussed in the following sections.

2 GEOTHERMAL DISTRICT HEATING

Geothermal district heating is defined as the use of one or more production fields as sources of heat to supply thermal energy to a group of buildings. Services available from a district heating system are space heating, domestic water heating, space cooling, and industrial process heat (Lund and Lienau, 2009). District heating can be defined as central heat delivery of buildings owned by different parties for heating purposes and for warm-water delivery (Konstantin, 2007). For instance German law defines that neither distances between heat generation and user nor size of the district heat net are part of the definition (BGH, 1986).

Advantages of geothermal district heating include (Lund and Lienau, 2009): reduction of fossil fuel consumption, reduction of emission of greenhouse gases, reduced heating costs, reduced fire hazard in buildings, possibly cogeneration of electrical power.

Even if district heating first-year costs are higher than those of a conventional system, a life-cycle cost analysis might still indicate economic feasibility of a district heating system. The 20-year annual average unit cost gives a rough comparison of the effect of fuel escalation and district heating system costs (Lund and Lienau, 2009).

Geothermal district heating systems are in operation in at least 12 countries, including: Iceland, France, Poland, Hungary, Turkey, Japan, Denmark and the U.S.A. A map view of existing district heating networks in Europe is shown in Figure 1. According to Lund and Lienau (2009), the most famous geothermal district heating project in the world is the Reykjavik municipal heating system (Hitaveita Reykjavikur) started in 1930. At the other end of the geothermal heating spectrum is the mini-district heating system for the Oregon Institute of Technology campus in Klamath Falls, Oregon. The 11-building campus has been heated by geothermal hot water since 1964 (Lund and Lienau, 2009).

Besides geothermal heat for the heat supply the following components are necessary: a pumping station, a station for controlling pressure and a net of pipes. At the side of the users a suitable connection for linking to the net has to exist as well as a distribution inside the building (Konstantin, 2007). District heating nets have typically a length of 20 km (Rebhan, 2002).

District heating nets are typically operated with hot water in a closed loop. On the side of the customer the heat is harvested using heat exchangers. Sometimes in the past even a direct connection without heat exchangers was used. Net temperatures are different depending on the season and on the efficiency of the connected buildings. Influx temperatures are typically between 70 °C and 130 °C. However, 130 °C is the maximum temperature suitable for the pipes in long-term operation mode. In reality such high temperature is only seldom needed at extremely cold days during the winter season (Konstantin, 2007). For water for domestic use the minimum temperature is 60 °C; therefore the influx temperature has to be higher than 70 °C (DVGW, 2013).

Lower process temperatures seem to be inacceptable due to arising problem with Legionella species. If so there will be a need for some kind of bacteriological treatment. Disadvantages of high temperature district heating systems are higher energy losses or higher insulation costs (Rebhan, 2002). These costs may be on the same order as the costs for meeting the technical requirements for low temperature district heating. However, these questions have to be addressed in the future.

Return flux temperatures depend on the energy efficiency of the respective buildings. For older buildings a return flux temperature of 70 °C is typical. In state of the art buildings a return flux temperature of 50 °C is sufficient. Lower temperatures are advantageous because they reduce energy losses (Konstantin, 2007).

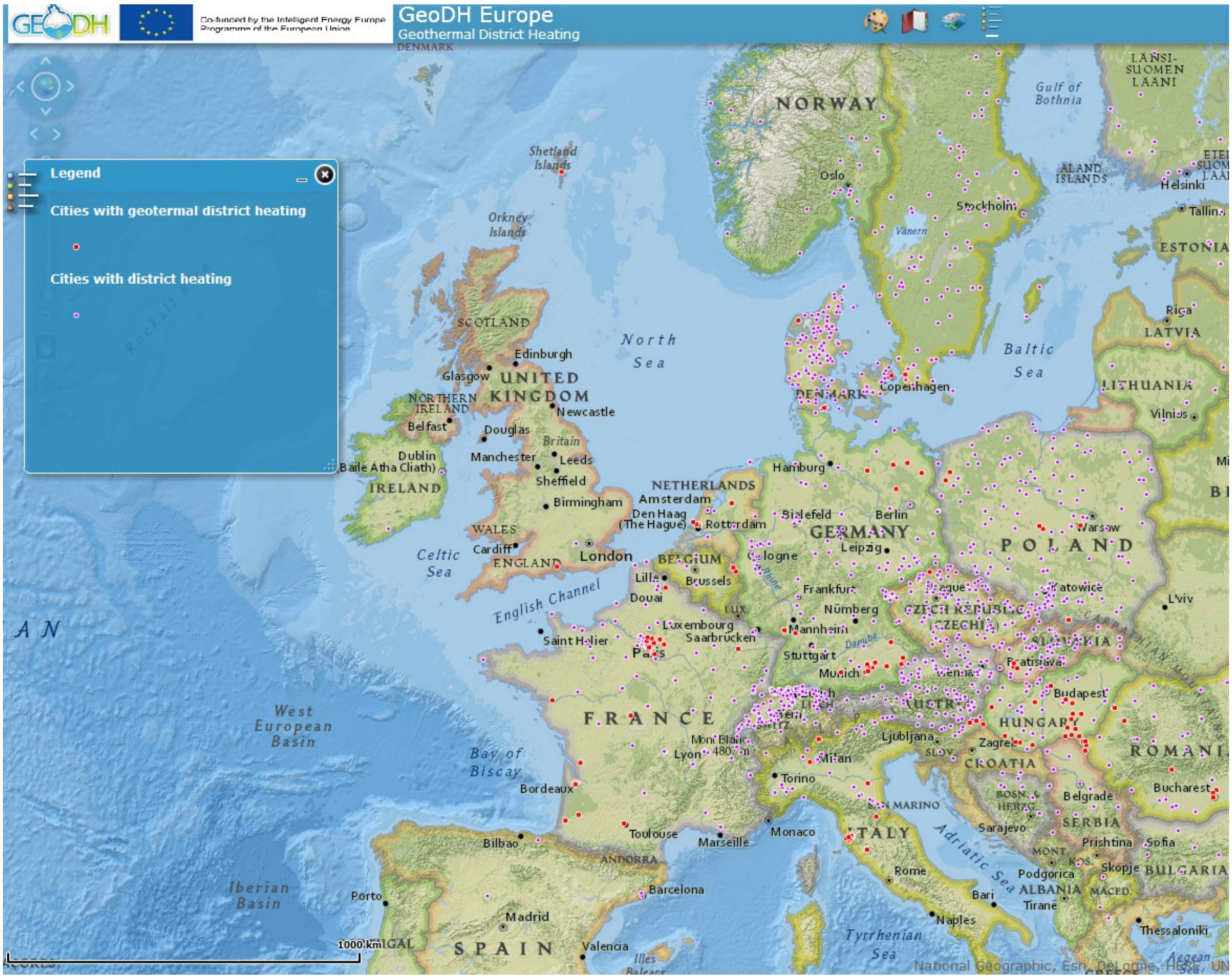

Figure 1 Web map viewer of the Geo-DH project showing European cities with existing (geothermal) district heating networks.

Dimensioning of a district heating net requires consideration of several parameters: Q_A (MW) specifies the sum of the connected loads; net peak load Q_H (MW) defines the highest required load of the overall network; the quotient of the two values is the loading ratio f_b; the heat required by the customer specifies the power feed from the network W_{th} (MWh/a); the transferred heat $W_{th,k}$ specifies the heat that actually arrives at the customers side after subtraction of all losses in the network. Such network-losses are a substantial problem of all district heating installations. By using state of the art pipelines such losses can be minimized to less than 1 %/km (Rebhan, 2002).

In the past district heating pipes have been laid within concrete channels; today due to economic reasons mostly buried pipework made of synthetic material are used. These are assembled of steel pipes surrounded by a thermal insulation made of polyurethane and a plastic coated sheath (Konstantin, 2007). For leakage detection purposes typically sensors are integrated.

The heat-transport capacity is proportional to the diameter of the used pipes. The diameter can be calculated using an approximation formula:

$$D_{LW} = 1.115 \cdot \Delta p^{-0.2} \left(\frac{Q}{\Delta T} \right)^{0.4} (mm) \tag{1}$$

The respective maximum heat transport capacity is then

$$Q_{\max} = 2.41 \cdot 10^{-8} \cdot D_{LW}^{2.5} \cdot \Delta p^{-0.5} \cdot \Delta T \ \ (MW) \tag{2}$$

with Δp the specific pressure loss in (Pa/m) and ΔT the temperature spread in-/return-flux in (K) and Q is the heat load (MW). Specific pressure losses are considered as constant.

For evaluating the economics of a district heating network the ratio between connected load and length of the network (MW/km) as well as the ratio between connected load and supply area are used.

District heating networks require a sophisticated pumping technology for delivering the hot water properly. The required electrical energy is a substantial expense factor (Konstantin, 2007).

One of the main advantages of district heating networks is that de-central heating systems are not needed. However, in terms of economics a cheap heat supply is necessary in the long run; this argument should favor the consideration of geothermal heat.

Based on data of Aalborg University (2013) the European Geothermal Energy Council (EGEC) stated in a press release recently (May 15^{th} 2014) that over 25% of the EU population lives in areas directly suitable for geothermal district heating. There is a large potential in Central and Eastern Europe, with geothermal district heating systems in operation in 22 European countries, where existing heat networks are well developed. For instance in Denmark almost 60 % of the households are connected to district heating. In Europe the GEODH project aims to promote geothermal district heating (www.geodh.eu). Based on their data in the EU-27 countries there are 3550 DH systems providing heat for 2160 cities and towns over 5000 inhabitants, thus satisfying 12 % of total heat demand of the population. The majority of the systems are fed by gas and only 1 % by renewables (mostly biomass).

If industrial process loads exist, they can be included. Process loads vary greatly among different industries; however, they definitely improve the load factor for district heating systems (Lund and Lienau, 2009).

District heating is usually economically feasible only in locations with a sufficiently long and cold winter season. It would be difficult to justify a district heating system in a location with less than 2200 heating hours. Typically, an area for which district heating is being considered should be characterized by buildings that have a least several stories and are situated relatively close to one another. (Lund and Lienau, 2009)

Lund and Lienau (2009) defined the following requirements for district heating:

- area to be serviced should have high-energy load densities
- connected loads should have a high-load factor, thereby promoting full use of equipment
- market areas should be as close as possible to thermal sources
- areas of new development or redevelopment often are necessary to form the core of the initial service area

3 POTENTIAL FOR INNOVATIONS

A great challenge for the operation of (long-distance) geothermal heating nets is that generally temperatures of geothermal sources – outside of high enthalpy regions and without drilling expensively into large depth – are too low for supplying a conventional district heating net where commonly temperatures between 90 °C and 130 °C are needed. A temperature of 70 °C which corresponds to a well-depth of approximately 2000 m while assuming average continental heat-flux, is clearly too low for direct heating purposes though very suitable as a heat source for a heat pump (Østergaard and Lund, 2011). Another solution is to connect buildings with low energy standard which typically only need heat delivered at 50 °C. However, this is probably not a solution for conversion of heating systems in existing holdings.

We promote to develop large scale demonstration projects where relatively cool geothermal heat is pushed to the necessary levels of temperature by boilers and/or heat-pumps in the apartment house. The required electrical power should then ideally be delivered form CO_2 free sources like wind energy. The use of geothermal energy in combination with a heat pump was considered already to be promising by Østergaard and Lund (2011). The heating of the water in the individual buildings from the original temperature to the needed influx temperatures of for instance common radiators reduces heat losses in the network. This is schematically depicted in Figure 2. Very high influx temperatures of 130 °C to cover rarely occurring very cold days are not necessary anymore, as the individual heat-pumps/boilers can be used for this.

An interesting additional result will be that unused contributed energy will remain in the net and others will benefit. By using smart nets those contributions could be prorated accordingly.

4 CONCLUSIONS

Geothermal energy can deliver heat and electrical power. While there is a strong competition with other renewables (wind, water, sun) with respect to power generation, the usage of geothermal energy for heating is unique. A transformation of kinetic energy into heat usually implies large losses while solar heat is often not sufficiently available in the winter time of colder regions. Furthermore, all resources currently used for heating in the colder regions of the Earth (coal, gas, oil) are emitting substantial amounts of CO_2.

The challenge for geothermal energy is to deliver sufficient heat at temperatures high enough for direct heating of buildings where most people live: in the urban areas. While near-distance heating systems are a successful concept for developing areas; the supply of heat via long-distance heating systems in housing stocks is a more difficult challenge.

An important advantage of geothermal energy is the possibility to install geothermal capacities even in existing building stocks, since above-ground installations are minimal and have nearly no impact on architecture or living quality. Nevertheless the geothermal heat has to be delivered to the consumer and for this district heating systems are necessary. The heat source can be replaced by geothermal energy where such systems already exist (substitution). However, we propose also the construction of completely new long-distance heating systems (innovation) in urban areas for the heat delivery of numerous deep geothermal drillings.

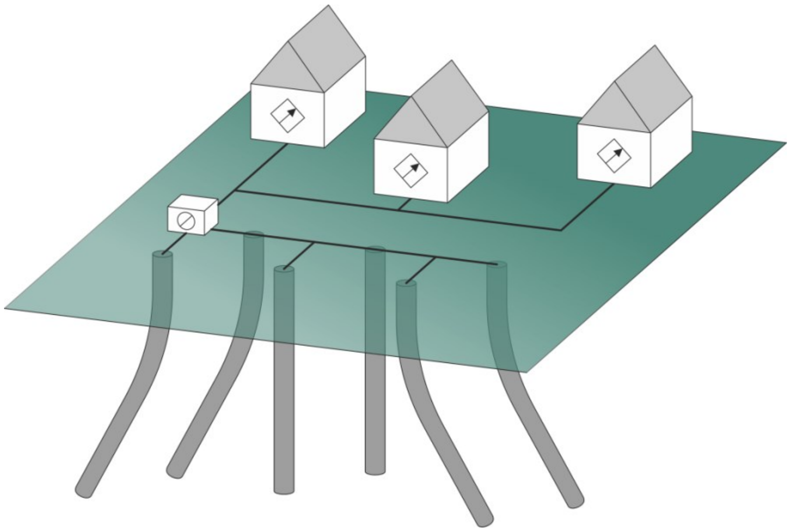

Figure 2 Scheme of a system of geothermal wells (extraction/injection) feeding a district heating grid.

Germany is aiming to transform its energy supply into a non-greenhouse gases emitting one. For this purpose geothermal heating is mandatory. Necessary requirements are district heat nets. For reduction of investment risks, the development of large scale systems is important. A system with only two well has a significantly higher risk to fail than a system with 20 wells. Experience shows that some wells are dry while other give far higher rates of productivity and also higher temperatures than expected. So, the risk has to be distributed to be minimized.

Depending on the temperature of geothermal fields, it may be advantageous to develop a hybrid system including, in addition to geothermal, a heat pump and/or conventional boiler for peaking purposes. (Lund and Lienau, 2009)

Today, long-distance heating systems have to compete on the market with other less expensive, but also by far less sustainable technologies. By seeing long-distance heating as a contribution where several generations will benefit, such a competition is obviously not meaningful (compare for instance with the building of sewerage systems or subways).

Instead, political decision makers should see the sustainable benefits of geothermal energy in combination with district heating and support the development with fair subsidies; after all, besides the environmental arguments even a financially pay-back is likely, but outside of typical economical time spans.

Future work includes summarizing the experiences with existing European district-heating systems, as well as showing additional concepts for demonstration projects. Also the challenges of such a sustainable transformation towards a CO_2-reduced heating for urban areas will be discussed.

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HESSEN Hessisches Ministerium für Umwelt, Energie, Landwirtschaft und Verbraucherschutz

Graduate School of Energy Science and Engineering

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