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Conversion of Conventional District Heating Systems in the Ruhr-Metropolitan Area, Western Germany, by Stepwise Integration of Geothermal Sources

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ABSTRACT

District heating systems combine heat sources and heat sinks. Existing systems are usually fed with thermal energy from fossil fuel power plants. New regulations and future requirements make it necessary, however, to consider alternative solutions. Thermal energy should be produced from sustainable, renewable and emission-free energy sources. Geothermal power and heating plants meet these requirements but they must be integrated into the existing systems. Because the existing district heating networks are laid in the densely populated and built-up areas, it is difficult to find suitable locations where new geothermal plants can be built to feed heat to such networks. With the help of various GIS software products and the available geological and geothermal records of public authorities and the plans of the existing district heating networks, suitable sites for possible geothermal power plants are to be determined.

1. INTRODUCTION

To open a significant market share for geothermal energy a competitive technology for their application must be provided to the main potential consumers. The most densely populated and energy consuming regions in Europe are the metropolitan areas around London, Paris and the Rhine-Ruhr-Region with 12 to 15 million people each, followed by large single cities such as Berlin, Brussels, Vienna, etc. Around 50 % of the total energy consumption of those is related to heat consumption over a range up to 100 °C. Most of them use already existing district heating systems based on fossil fired power plants. Some of them are supported by waste incineration or further industry sources (from steel, glass etc. –production).

In Germany 13 % of the final energy is provided by renewable energy systems. The heat market consists 10 % of renewable generated thermal energy. The share of building heating represents 35 % of Germany's final energy demand (without process heat < 100 °C). For that reason it is intended to convert conventional district heating systems towards renewable sources; geothermal energy systems are in favour to take a leading role.

In the Ruhr metropolitan area – an agglomeration of 50 cities with a population of ≥ 5 million at 4,400 km² – a district heating network exists with a total length of 4,300 km. Shortly this network will get some additional connections for further redundancy. This will be one of the largest district heating networks in Europe, mostly served by fossil fired power plants.

The challenges will be to:

a) subsequently introduce geothermal heat resources on a temperature level of 90 – 130 °C into the existing heating infrastructures while removing fossil sources;
b) combine them with additional input from the industry and others into smart heating grids;
c) develop EGS for sedimentary strata and structures;
d) communicate this to the public.

The authors of this paper will present a concept of the integration of geothermal sources into the existing infrastructure of a district heating network with an example of the Ruhr Metropolitan Area. Subject of this work is not only the geological conditions but the technical practicability. Since this project is supposed to be realized in the near future, attention is paid to the integration of geothermal plants in urban, regional and environmental planning processes as well as the placement of geothermal plants in a densely populated area.

2. A NEED TO CHANGE - EU-POLITICAL BACKGROUND

Nowadays the utilization of energy has multiple purposes. In early stages of men kind combustion was used for heating only. Other applications like transforming chemical energy into thermal energy which then is used to be transformed into kinetic energy are very common in modern civilization. But still space heating is one of the most used final energies besides generating electricity or energy for transportation. As an example of an industrial nation Germany uses 50 % of its final energy in the form of thermal energy, 20 % for electricity, and 30 % for transportation according to UBA (2012). In total around 40 % are used for space heating, but it can be assumed that way more than 50 % of the total energy consumption is demanded for space heating in cities and metropolitan areas. Still the European energy market is dominated by conventional energy consumption. According to EC (2013) renewables had a share of more than 14 % in 2012. Within the renewable energies the share is unbalanced between power generation, hot water/heating, and transport fuel (REN21 2013). Around two thirds of the world renewable capacity is used for power generation, 28 % for the use of thermal energy, and just 5 % for transport fuels. This matches the unbalance of renewables all over Europe. Especially the German Renewable Energy Act pushed the development of renewable electrical energy from 7 % in 2003 to around 25 % in 2013. On the part of the renewable thermal energy the share stagnates for the last three years at 10 % (ZSW 2013). Geothermal energy systems have the potential to play a major role on the hand of renewable heating energy. Both shallow and deep geothermal systems are able to provide energy at different temperature levels, demands, and loads. These properties are needed for a future smart grid in an urban environment. Geothermal energy systems are integrated into the market of heating energy already. But the share can be expanded dramatically if the topic of renewable heating shows up in the agenda for renewable energies more often. All countries of the European Union passed the national renewable energy action plans (EC 2009). This directive contents each country's target to fulfil the "three-20-target" of the EU to reduce greenhouse gas emissions by 20 %, increase energy efficacy by 20 %, and to have 20 % renewable energies of the total energy consumption by 2020. Figure 1 gives an overview over the target and actual values of renewable thermal energy and geothermal energy systems for Germany as an example of an industrial country.

In most cases shallow or deep geothermal energy systems represent decentralized systems. In terms of efficiency it makes sense to combine systems (Horlock 1987). This paper deals only with deep geothermal systems but nevertheless same discussion can be made for shallow geothermal systems with the same arguments. For efficiency there is the option of having more than one geothermal heating plant. Thus, both power plants could run at the highest efficiency. E.g. one would deal with the production of electrical power and the other one with the heating demand between spring and fall. During the winter months both systems would provide as much thermal energy as needed. Literally on the other hand of the system it makes sense to provide as many consumers with thermal energy as possible. Thus the time-variation curve of the loads will have a lower variation which then again is much better for the efficiency of the entire system since it is able to run at its ideal operating point. The closer the consumers are the less thermal energy loss through the pipelines occurs. A geothermal district heating network contains at least one geothermal power or heating plant which is connected via insulated pipes with a consumer. Such a system represents an ideal solution for renewable heating demands in urban areas since it is a zero emission heating system which is independent of season, weather, or time of the day.

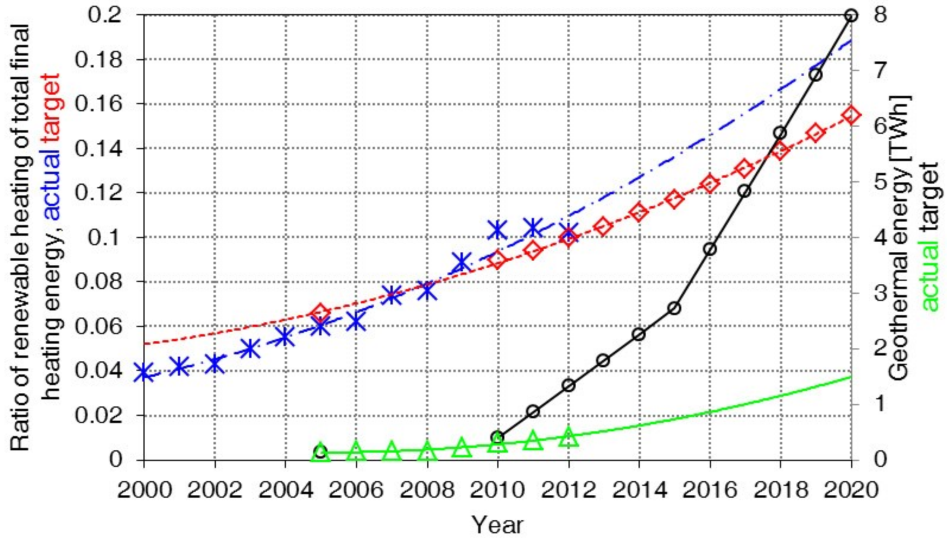

Figure 1: Comparison of target and actual ratio of renewable heating to conventional heating energies for Germany. Final energy values are compared. The NREAP Germany target values for each year are shown as red rhombuses and a red line, the actual values are symbolized by the blue crosses. The blue line represents the actual values regression (y=2E-78e0.09x; R^2=0.97). Green coloured is the actual geothermal energy in TWh with its green regression trend (y = 0,0061x^2 - 24,605x + 24668; R^2=0.98). Black circled and lined represents the target NREAP Germany geothermal energy. Data sources: destatis 2014, EC 2009, ZSW 2013

3. OVERVIEW ABOUT GEOTHERMAL DISTRICT HEATING SYSTEMS

3.1 Geothermal District Heating Networks

Geothermal power and heating plants feed the connected district heating network with thermal energy and get back lower energy. This procedure is operated with a heat exchanger so that both the geothermal plant as well as the district heating network have their own closed circuit. This is particularly important for the district heating pipes, which are operated with deionized and degassed water to protect the pipeline from the inside (Schäfer 2001). Larger (geothermal) district heating systems are divided additionally into primary and secondary networks. The former operates as a thermal reservoir and distribution network for longer distances. Several secondary networks are connected to this on the one side and to the substations of the consumers on the other side.

Basically each kind of geothermal energy is useable for such a system as long as the provided temperature is greater than or equal to the designed temperature. The designed temperature again depends on the highest customer's thermal energy demand during the year. This is a relation between temperature, volumetric flow rate and pressure. Besides the possibility of delivering the needed temperature directly from the geothermal plant a so called cold district heating network can be used as well. Here through the network lower temperatures are provided which then again are heated up directly at the customer's side with a heat pump.

The larger a geothermal district heating network is, the less redundancy it needs. If only one geothermal plant is part of the system, it is necessary to have an additional heating system, both as backup and for peak loads since a regular geothermal plant's controllability is limited. Within larger networks with many geothermal plants it is possible to run those systems with less redundancy. It is important to operate a geothermal plant with a high utilization rate all year long. On the one hand – for the borehole - the plants itself needs to run within a range of constant flow rates. Downhole lineshaft pumps are controllable between almost 50 % and 100 % in terms of pumping rate (Frost 2010), electric submersible pumps around 70 % to 100 %. The most complex circumstance is played by the fact that in most cases the demand is flexible due to changes of season or weather. For this case either additional peak load systems or a smart use of the geothermal energy supply are required. If the temperatures are at the right level, electricity generation is an option for higher utilization rates during warmer periods of the year. Thus geothermal power plants are able to generate electricity as long as the other geothermal heating plants suffice for the thermal energy demand. If this demand rises it has to be switched from electricity generation to heating production. In this way, more geothermal plants in a district heating system are able to run at their best operating point and more important to run as many hours as possible.

3.2 Development of district heating networks in Europe

According to EGEC (2013) in Europe around 240 geothermal district heating networks exist with a total of 4,300 MW_{th}. The number of such systems has increased steadily in recent years. Before, due to cheaper fossil energy prices, the geothermal district heating market experienced a conservative growth. Unlike in the 70’s during the first and second oil crisis geothermal district heating systems boomed (Knutzen 2014). Today’s relatively high fossil energy prices and the awareness of sustainability let the market rise again with a total of additional 215 within Europe. Besides, district heating networks are getting more attractive for electricity utilities again. The calculability for electricity prices is not given any more since the impact of the renewable power energy is getting bigger. An advantage of those district heating systems is a monopoly-like structure (Söderholm, Wårell 2011). A third party access is almost not possible. Thus this business segment is projectable for profits. For the customers competition would have some financial benefits but it is not easy to implement since the involvement of the thermal energy producer and distributer are high. But this is an option for larger geothermal district heating systems with geothermal plants from more than one operator. Nevertheless frequent technical arrangements must be made for smooth running process because little changes of the production mix can have a big impact on the system optimization.

4. METHOD FOR INTEGRATING GEOTHERMAL ENERGY FOR EXISTING DISTRICT HEATING

4.1 Integrating geothermal plants in existing district heating networks

Spread out all over Europe around 6,000 district heating networks exist (Lund, Werner 2013). Ca. 4,200 of them are displayed in the map in Figure 2. For historical reasons the East European countries have a high amount of district heating networks. In Western Europe it is more common at high heat demand density areas. All over the world there were different reasons to build and use a district heating system. Most of those systems are fossil fired. Geothermal district heating systems usually go along with a new designed district heating network because it is built in the best geothermal conditions in combination with thermal energy users located. Worldwide in a few cases geothermal plants were combined with existing district heating networks. In those the existing infrastructure including the substations is fully usable for heat from renewable energy sources. If an existing district heating system is used the costs for the infrastructure can be reduced. As an example it costs around one million Euros per kilometre for a geothermal district heating system in Bavaria, Germany that has to be constructed (Knapek 2014). For this reason it is highly attractive to integrate geothermal plants in existing district heating systems. But the most important is the feed temperature. This must meet the system requirements, otherwise it would not be useable. Too high temperatures are acceptable, too low temperatures are not. In those cases the temperature level must be raised even if the enthalpy level stays the same.

For the integration of geothermal energies into an existing district heating system many decisions have to be made. Very important ones include:

- the temperature level
- the flow rate (and therefore the thermal power)
- the flexibility of the heating system in terms of being able to lower or increase the thermal energy output over a certain amount of time
- the yearly operation hours
- the controllability of the heating production.

Geothermal plants are predestined to cover the base load all year long with almost 8760 operating hours. The thermal energy demand on the hand of the users is changing frequently but in many times not rapidly. Since the entire pipeline system, which is running with water as transport medium, acts as a storage system itself, minor changes of the demand are manageable. More complex are longer periods of high temperature demand. For this scenario a district heating network must be designed. Customers should not be cold during harsher winter periods and industrial customers need access to the guaranteed amount of thermal energy for their processes. For this case backup systems are necessary. Those can be either geothermal power plants which switch from electricity output to thermal energy output or any kind of combustion system like biomass or old integrated fossil fired heating plants. Since the operational hours are limited an alternating operation is advisable to run all components profitable. In areas with a high heat demand density district heating systems are ideally used. Many customers with a high thermal energy demand are located within a small area. The distances between the consumers, the temperature loss due to transportation, and the electricity used for the circulation pumps are low. Europe has many of those areas around the bigger capitols of some countries and areas with a high density of industrial complexes (Figure 2). In many of those high heat demand density areas district heating networks already exist which are used for space heating or for process heat. Those regions are favoured to integrate geothermal energy as a base load renewable energy source.

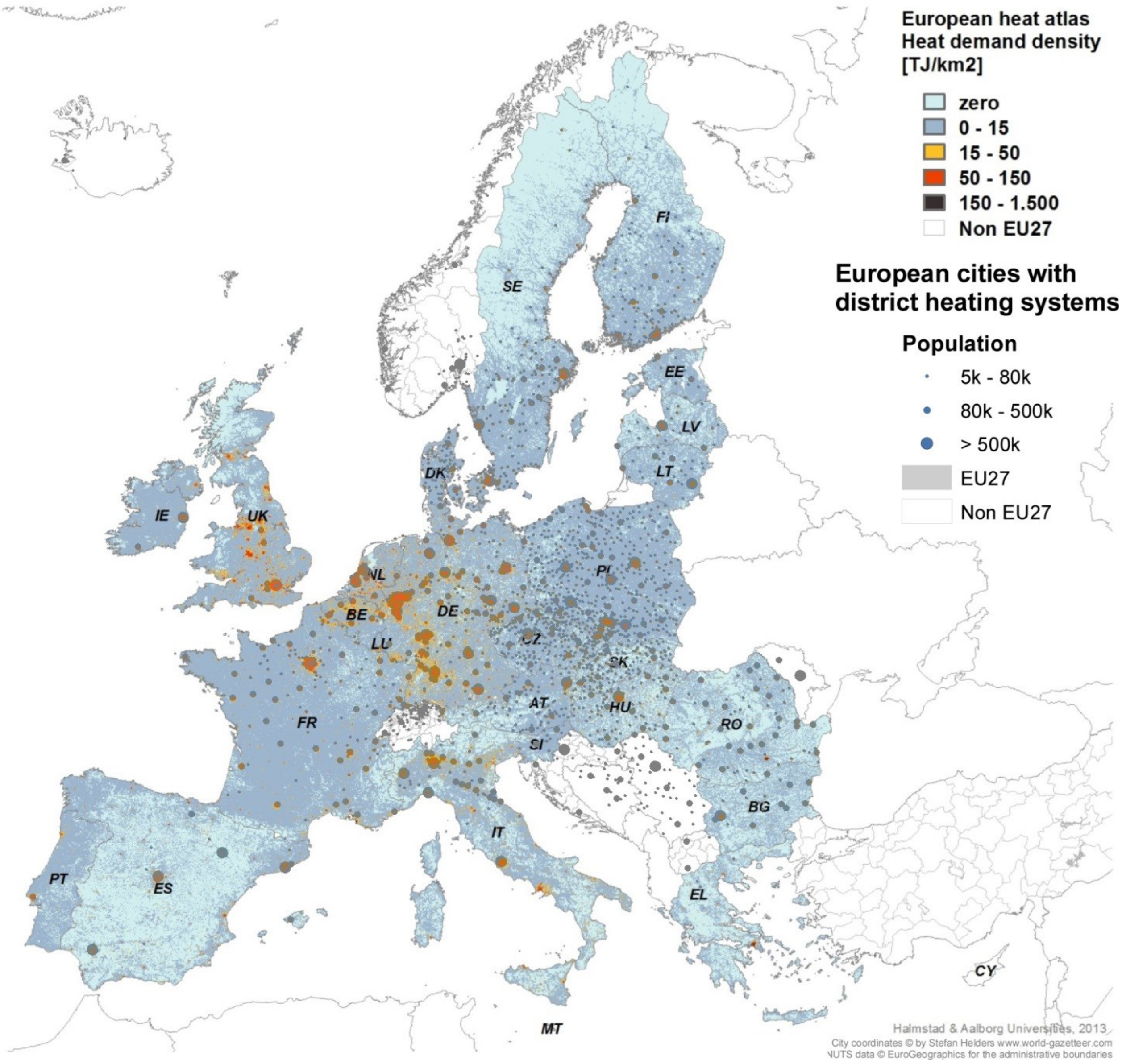

Figure 2: Each dark Spot symbolizes one of 4174 District Heating Networks within Europe, 3549 within the EU 27 in which 60 million citizens (12 % of population) have access to the network. The background colour of the map demonstrates the heat demand density. On the lower end are the blue colour tones on the higher end the red colour tones. High density areas are located in Northern England and metro area of London, Paris and Berlin, parts of the Netherlands and Belgium, Western and South-western Germany. sources: Lund and Werner 2011 which refer to Halmstad University DHC Database, Lund and Werner 2013

Future district heating systems need to fulfil the future demand on space heating. In the early ages of district heating systems around the 1880s the feed temperatures were high and the flexibility of the entire system was low. Current district heating networks are appropriate for today's needs. But the temperature level will fall further. The reason for this is less demands due to thermal building restoration and therefore a lower temperature level as well as an increase of renewable energy supply. In 1990 around 4 % renewable energies were used in district heating systems in Europe (RHC 2013). From there on an almost linear run occurred to around 18 % in 2012. Predictions of Euroheat & Power and RHC (2013) are made that this trend will continue with the same gradient. This means that future heating systems have to be much more flexible in producing thermal energy on the one hand and on the other to fulfil lower and/or more flexible temperature demands. The building stock will change continuously off being consumer towards being consumer, producer, and energy storage altogether. For those reasons existing district heating networks have to change. According to Lund et al. (2010) district heating systems are (in Denmark) the best way for space heating in terms of CO_2 reduction, cost of thermal energy for the user, and the fuel demand. Depending on the distance between the heat source and sink heat pump systems would be an alternative for areas with less heat demand density and therefore longer pipeline length. Nevertheless geothermal energy systems in combination with other renewable heating energies like solar heat and biomass are able to assume on behalf of thermal energy generation for the future smart cities.

4.2 Urban and Environmental Planning as a Decision Tool

Finding the right locations for geothermal plants which feed into an existing district heating systems is one of the major challenges. The right location is defined by an area in which the geothermal and geological conditions meet the needs for the district heating system while the people living in the neighbourhood are not disturbed and the nature surrounding is not affected in terms of sustainability.

As a decision making tool any kind of geographic information system (GIS) can be used. Thus a graphical solution is created with which the decision makers can handle different kinds of input data. At any early stage of a project the scale of the data will be much smaller and magnified towards the end of the decision making process. The used datasets are divided into the following groups:

- subsurface areas
    - all kinds of geological and geothermal information regarding geophysical and geochemical data of the target formation for theoretical or practical potentials no matter what geothermal system is used
- above-ground areas
    - all kinds of environmental protection zones
    - land-use plan
    - location of the district heating network and power plants
    - infrastructure like roads or rails
    - buildings and other sorts of constructions
    - (noise) emissions and immissions.

Those datasets are the base for the research to find the right locations for geothermal power or heating plants, which should be connected to an existing district heating network. For this everything has to be digitalized if not available, followed by the georeferencing process. All datasets – sorted by inclusion zones or exclusion zones – have to be loaded into a GIS program. After processing the data at different scales suitable areas remain.

Often the used datasets imply plenty of information, which needs to be sorted before use. Besides dividing it up into two groups of inclusion and exclusion zones the scale is very important. Each dataset was recorded at a different scale, which means that information of smaller scales is included, the one from larger scales is not. Thus a decision pyramid is created. In early stages of such a project the most important part is to narrow down the prospect. Easy to process are those areas in which the possibilities of acting are clear, as being allowed, forbidden, or just not possible to construct a geothermal plant. Those are e.g. built-up areas, water ways, or nature protection areas. More complex are areas in which prohibitions occur at the largest scale or in which restrictions are made. The work with authorities at different levels might be necessary. This GIS analysis is possible to use for projects from scratch on to the detail planning.

The protection categories depend on the life cycle of the geothermal plant. Here three differentiations have to be made:

1. constructing and drilling phase
2. operating phase

Figure 3, 4, 5: Map extraction (16 km x 14 km) of a part of the city of Recklinghausen, Germany. Figure 3 (left): Dark red coloured is the existing district heating network which should be used for geothermal feed. The coloured polygons represent different natural reserves which represent possible exclusion zones for geothermal heating plants. Figure 4: The different colours represent different kinds of land-use planning which are not explained here. With this thermal heat demand for the research areas can be estimated as well as possible locations for the geothermal heating plant. Figure 5 (right): Sections of infrastructure are pictured like streets (black lines), railroads (black crossed lines), and buildings (red polygons).

3. repair, revision, or damage phase.

For all those cases the regularities have to be maintained. Reasons of those protection categories are the protection of the people's health, contamination control of ground water and waters, forests and the nature's flora and fauna protection. The latter is the most regulated category with directives, laws and voluntary requirements. Those can be made on different authority or legislative levels which again commission lower authorities to implement those. Noteworthy are worldwide requirements (RAMSAR, UN Treaty Series No. 14583), directives of the European Union (Natura 2000, 92/43/EEC, 79/409/EEC; EU-WFD, 2000/60/EC), and national as well as state laws (nature protection and nature conservation legislations).

Some examples for implementing different data sets are shown from Figure 3 to Figure 5. It is interesting that existing district heating systems can be part of a later adopted protection zone. Integration of geothermal energy is difficult at those spots. Nevertheless due to directional drilling many smaller zones don't bother for the utilization of geothermal reservoirs. But then it is important to find a location for the geothermal plant including the legal space to other areas.

4.3 Connection of Geothermal Power Plants with District Heating Network

Larger district heating networks are designed with several different diameters of the pipelines. Usually the connection to the thermal energy generator has the widest diameter, the customer the narrowest. But this depends on the layout of the network itself (tree, loop, or combination). To feed geothermal energy to a district heating system supply points have to be found. This requires a close collaboration with the operator of the district heating network. Unproblematic are supply points which used to be connections for an existing fossil fuel heating or power plant. If similar power and flow rates are provided by one or several geothermal plants a connection to this supply point is easily manageable. In case of connecting a geothermal plant anywhere to the network some flow simulations of the network have to be made. This is not trivial. The simulation of larger district heating networks is very time and computationally intensive and therefore in many cases not simulated dynamically but statically. If a right supply point within the right area (see 4.2) is found, the connections can be prepared or constructed.

Further research has to be made which analyses the economical reasonable distances between a geothermal power or heating plant and the existing district heating network. This depends on the temperature difference between feed pipe and the surroundings, the isolation grade, the flow rate, sell price per kWh, actual costs, and many more.

4.4 Example Ruhr Metropolitan Area

In the Ruhr metropolitan area a district heating network with more than 4,300 km length exists. According to BET (2013) 6,500 GWh were used in 2012 with a thermal output of 2,300 MW. Around 3 % of the thermal energy was generated by renewable energies (biomass), 11 % surplus heat from industry, 25 % waste combustion, and 61 % from fossil fired heating and power plants (coal, gas). The future demand of thermal energy will be reduced to 86 % of today's demand until 2050. Germany's space heating demand will be divided in half in the same period. Due to the climate protection targets of the EU, Germany, the state of North Rhine Westphalia, and the municipalities the mix of the thermal energy generation for the district heating network has to change towards more renewable energies and less fossil energy incineration.

For the Ruhr metropolitan area a research will be made which investigates the location for certain geothermal heating plants. In the Ruhr metropolitan area around 5 million people live on 4,400 km^2. Historically many industrial complexes were established that worked in the field of coal mining or coal processing. In 2018 the last two coal mines will have been closed and the phase of structural change will have enclosed. For this region an investigation of the right spots for geothermal plants will be made which considers the local conditions. There are areas which need certain attention and which are regulated like natural habitats, birds and habitat directive (Natura 2000), RAMSAR boundaries, §62 biotopes, natural reserves, protected landscapes, water protection areas and so on. The usage of the geothermal reservoir doesn't affect those zones directly but indirectly through the building and construction sides of the geothermal infrastructure. With the possibility of controlled directional drilling some smaller areas can be avoided with this technique. The protection scale is based on different levels, not all of those areas are highly protected. In certain cases authority can demand certain offers. Besides that all areas which are used already for buildings, roads, railways, waterways, and so on, are counted as exclusion areas.

For the exclusion protection categories that are taken into account see Table 1.

Table 1: Protection zones that take account for integration of geothermal plants into the existing district heating network of Ruhr metropolitan area

Protection Category	Law, Paragraph
§62-Biotops	Bundesnaturschutzgesetz §30, Landschaftsgesetz NRW §62
Natura 2000	Habitats Directive 92/43/EEC, Bird Directive 79/409/EEC
Nature reserve	Bundesnaturschutzgesetz §23
RAMSAR	UN Treaty Series No. 14583
Nature park	Bundesnaturschutzgesetz §27
National park	Bundesnaturschutzgesetz §24

Man and the Biosphere Programme, Biospehre Reserves	Bundesnaturschutzgesetz §25
Protected landscape area	Bundesnaturschutzgesetz §26
Natural monument	Bundesnaturschutzgesetz §28
BSN (protection zones for nature)	Bezirksregierungen Düsseldorf, Münster, Arnsberg
Environmental impact assessment	UVPG, UVPG NW
Water protection zones	LANUV (authority)
Flood areas	MKULNV (authority)
Water framework directive	Directive 2000/60/EC
Federal emission control act	Bundes-Immissionsschutzgesetz, TA Lärm

On the other hand are the inclusions. Here mainly the geothermal and geological data matter as well as the location of the existing district heating network with its power and/or heat plants. Geological eras are Carboniferous and Devonian at a depth between 3,000 m and around 5,000 m. The formations dip down northwards. Possible geothermal systems that can be used are drillings into tectonic extension fold structures or multi-sidetrack drillings in sedimentary formations with appropriate thicknesses for EGS. On the hand of the temperatures there are to expect different temperature prediction (Table 2). Realistic geothermal gradients between 3 K per 100 m and 3.5 K per 100 m are expected. Those are in the range of the of the GeoELEC temperature predictions. The northwest of Ruhr metropolitan region features the higher temperature values, the southeast the lower. Those values are modelled, not measured, as part of the GeoELEC project by the EGEC (Limberger 2013). Published data from the geological survey reveal that temperatures at 5000 m depth and below are higher than expected.

Table 2: Expected temperatures in depth between surface and 7000 m. The geothermal gradient is displayed between 3 K per 100 m to 3.5 K per 100 m. The middle column's values are extracted from GeoELEC (2013) project. All values are calculated but the value for 6000 m at the right column.

K/100m	3.00	3.25	3.50	GeoELEC from	GeoELEC to	Geological Survey North Rhine Westphalia	
0 m	10 °C	10 °C	10 °C	10 °C	10 °C	10 °C	10 °C
1000 m	40 °C	43 °C	45 °C	35 °C	46 °C	(exploration drilling Münsterland 1, 40 km NE of investigation area)	
2000 m	70 °C	75 °C	80 °C	70 °C	79 °C		
3000 m	100 °C	108 °C	115 °C	100 °C	105 °C		
4000 m	130 °C	140 °C	150 °C	120 °C	140 °C		
5000 m	160 °C	173 °C	185 °C	143 °C	158 °C	156 °C	178 °C
6000 m	190 °C	205 °C	220 °C	-	-	200 °C	
7000 m	220 °C	238 °C	255 °C	180 °C	200 °C		

Additional to the environmental and urban planning as well as the geological and geothermal conditions, some simulations on the district heating network itself will be made. Attention is paid to hydro flow simulations regarding the possible exchange of a few fuel fired heating plants with large thermal power outlet to several smaller geothermal powered heating plants with less thermal power outlet. The existing district heating pipes differ in diameter and length. The fewer branches follow, the less the difference in diameters and the other way around. Because the network of Ruhr metropolitan region is highly branched with different types of pipe layouts, like tree or loop system, it is necessary to investigate the possible connections of new or reused old substations since geothermal heating plants could be connected all over the network.

5. CONCLUSION AND OUTLOOK

More than 50 % of the total energy consumption in cities or metropolitan regions is used for space heating and thermal energy on a level of less than 100 °C. The development of renewable heat is necessary since it is already declared in international agreements but not yet totally implemented. Geothermal energy systems combined with district heating networks are privileged to fulfil the task of providing renewable heat since the thermal energy source is available time, season, and weather independent as well as CO_2 and particulates free. To utilize many thermal energy customers, connected through a district heating network, with a high performance ratio are beneficial in an area with high heat demand densities. The integration into existing networks is possible as long as the temperature level is high enough. Otherwise it has to be raised to the right level or a cold geothermal district heating network has to be designed instead.

District heating networks will change since the buildings stock will change dramatically in the future. They need to be more flexible and provide thermal energy at lower temperatures.

For the integration of geothermal energy systems into district heating networks the right locations for newly constructed geothermal heating or power plants have to be found. The right location is defined by an area in which the geothermal and geological conditions meet the needs for the district heating system while the people living in the neighbourhood are not disturbed and the surrounding environment is not affected in terms of sustainability. For this GIS programs can be used which allow a graphical solution to find locations in a region or an area with high density of population and building-sites as well as many regulation for the nature site.

On variable plays the distance of geothermal plants to the existing district heating network. This has to be taken into account, too, but is more dependent on finances than on the technical side. This has to be investigated further more. But the same GIS method is useable and will be integrated into the research which will carry on for an example detail planning for the integration of geothermal energy systems into the district heating network of Ruhr metropolitan area. This network has a length of 4,300 km and is one of the biggest district heating networks in Europe.

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