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PRELIMINARY FEASIBILITY ASSESSMENT FOR ROLLING OUT 5GDHC TECHNOLOGY IN 7 FOLLOWER REGIONS

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Abbreviations

4GDHC	4th generation district heat and cold
5GDHC	5th generation district heat and cold
AGFW	Energieeffizienzverband für Wärme, Kälte und KWK e. V.
AVBFernwärmeV	Verordnung über Allgemeine Bedingungen für die Versorgung mit Fernwärme
BAFA	Bundesamt für Wirtschaft und Ausfuhrkontrolle (Federal Office of Economics and Export Control)
BAT	Best available technique
BDEW	Bundesverband für Energie- und Wasserwirtschaft (Federal Association for Energy and Water Management)
BMWi	Bundesministerium für Wirtschaft und Energie (Federal Ministry for Economic Affairs and Energy)
CHP	Combined heat and power
CO2	Carbon dioxide
DH	Direct heating
DHN	District heating network
EEWärmeG	Erneuerbare-Energien-Wärmegesetz (Renewable Energies Heat Act)
EnEG	Energieeinsparungsgesetz (Energy Conservation Act)
EnEV	Energieeinsparverordnung (Energy Saving Ordinance)
GEG	Gebäudeenergiegesetz (Building Energy Act)
GWh	Gigawatt hour
km	Kilometer
KWKG	Kraft-Wärme-Kopplungs-Gesetz (Combined Heat and Power Act)
LANUV	Landesamt für Natur, Umwelt und Verbraucherschutz (State Office for Nature, Environment and Consumer Protection)
MW	Megawatt
MWh	Megawatt hour
NRW	Nordrhein-Westfalen
TPA	Third party access
TWh	Terawatt hour

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1. Introduction

Activities in the Long-term work package aim to sustain and roll out D2Grids outputs to a wide variety of target groups, including policymakers, financial investors, professionals, SMEs and other companies in the DHC industry, as well as to new territories (“follower regions”). Transnational roll-out beyond pilot sites will be facilitated by assessing replication potential of 5GDHC in these follower regions and preparing specific local action plans. The regional vision development and preliminary feasibility assessment for rolling out 5GDHC technology is carried in this deliverable for each of the 7 follower regions defined for this project, namely: Parkstad Limburg (NL); North-East France; Luxembourg; Flanders (BE); Ruhr-area (DE); Scotland; East Midlands (UK). It aims to define ambitions for low-carbon heating & cooling and to assess the feasibility and potential of 5GDHC's roll-out.

The D2Grids project, has ambitious goals for the future. Five years after the project ends, 2 million m^2 of floor area in North-West Europe should be served by 5GDHC, of which 1.5 million m^2 by scaling up the D2Grids pilots and 0.5 million m^2 by rolling out into the follower regions. The overall capacity of these 5GDHC systems should be 180,000 MWh/a, including 100,000 MWh/a additional renewable energy source capacity. 10 years after the end of D2Grids, the total floor area should be 5 million m^2 and the overall capacity 450,000 MWh/a. This document presents a template for regional vision development, which describes ambitions of each of the follower regions on how the region can contribute towards this goal of 0.5 million m^2 of floor area after 5 years. To inform this regional vision, a preliminary feasibility assessment is conducted first (see D.LT.1.1).

The goal of the feasibility assessment is to find the potential of deploying 5GDHC in the follower regions within 5 years after the project ends, as well as finding possible longer-term opportunities. This is done by mapping strengths, weaknesses, barriers and opportunities of 5GDHC for each of the follower regions. The assessment consists of 5 categories: renewable sources; existing infrastructure and planned developments; thermal demand & supply profiles; legal & policy framework; financing options.

2. Characterising the region

The analysis will focus on the Ruhr area ("Ruhrgebiet"), a polycentric urban area in North Rhine-Westphalia ("NRW"). The Ruhr region takes its name from the river Ruhr, which runs along the southern edge of the region. The focus of the Ruhr region is on industry. As early as 1850, its coal mining and iron and steel industries made it one of the most important coal and steel regions in Europe.

North Rhine-Westphalia (NRW) is a German state in Western Germany. NRW is covering an area of 34 092 km^2, which makes it the fourth largest state in Germany. It has a population of 17.9 million making it the largest state by population and most densely populated state in Germany. NRW has always been Germany's powerhouse with the largest economy among the German states by GDP figures. Figure 1 displays the different regions in NRW. The Ruhr area is marked in grey.

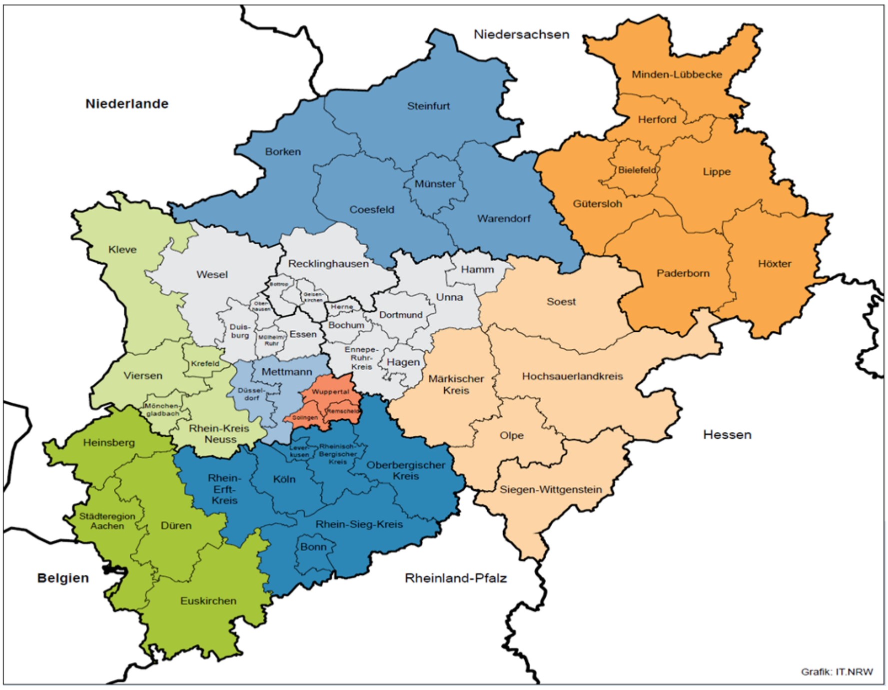

Figure 1: The Ruhr area in NRW [1]

The Ruhr area is located in NRW and accounts for about one third of the population. Today, 5.11 million inhabitants live in the Ruhr area, which covers an area of 4439 km^2 with 1152 hab/km^2. It is the sixth largest metropolitan region in Europe. Around 39.1 % of the area is used for residential areas and traffic, 58 % is covered by vegetation (including agriculture) and 2.9 % is covered by water [2]. The Ruhr area contains four rural districts and eleven cities, which are independently administrated on municipal level, although there exists the supracommunal "Regionalverband Ruhr" institution. The districts are Wesel, Recklinghausen, Unna and Ennepe-Ruhr-Kreis. The independent cities are Hamm, Dortmund, Hagen, Herne, Bochum, Gelsenkirchen, Essen, Bottrop, Oberhausen, Muhlheim an der Ruhr and Duisburg. The biggest city is Dortmund with 588 250 residents and the smallest municipality is Sonsbeck with 8763 residents. [3]. The Ruhr area does not have a typical centre but is spread out relatively even in terms of settlement structure.

The Ruhr area uses mainly gas, oil and district heating for its heating purposes. Even though the heat supply is mainly based on fossil fuels, the share of district heating is not insignificant. Europe's largest district heating network is located in the Ruhr area. This is a substantial aspect in the design of a sustainable energy supply system.

The Ruhr region has a comparatively low proportion of residential buildings with more than six residential units compared to other cities in Germany. The share of single- and two-family homes in the Ruhr area is higher than in the comparative cities. Most buildings in the Ruhr area are older, low energy-performing buildings. The highest average energy consumption values have unrenovated residential buildings built before 1979. In the Ruhr area, the proportion of residential buildings built before 1979 is 73 percent. By comparison, 60% of residential buildings in Germany were built before 1979.

Three natural units intersect each other within the borders of the Ruhr area's topography: Westphalian Basin (North and East), Lower Rhine Plain (South), and Rhenish Mountains (West). The mean elevation level is low, that is, within the core area no higher natural elevations exist; the outer area features a few steeper elevation slopes such as outcrops or stream cutting erosions and some greater altitudes at the southern borders.

The Ruhr area is located within Europe's moderate climatic zone and is influenced by maritime climate sector. Thereby mild winter temperatures result. The historically averaged (1970 – 2015) monthly mean air temperatures lay between 3 °C in January to 19 °C in July, for Dusseldorf, a city not part of the investigation area, but connecting to it as its south-western border.

Figure 2: Map of the Ruhr area [3]

3. Analysis

3.1. Heating regime

3.1.1. Current dominant heating technology or carrier in the region

Currently dominant heating technology in the region

In the following, district heating in NRW (since no separate data for Ruhr area is available) is examined in more detail due to the increased importance in this context. District heating is used in many sectors. In the industry it is used, for example, as process heat, whereas in households district heating is mainly used for space heating and hot water. It is interesting to consider the district heating consumption of the different sectors and the amount of district heating consumption in NRW. In addition, the heating systems of the apartments in NRW should be considered in order to know the current dominant heating technology.

In 2017 NRW had a heat consumption of 313.07[1] TWh. To determine the heat consumption of NRW, the heat share (55.62 %) of the end energy consumption of Germany was administered as a reference value. The heat share was applied to the end energy consumption of NRW in order to obtain an estimation of the heat consumption.

In NRW a total of 26.4 TWh district heat was consumed in 2017, of which 15 TWh was used by the industry, 8.7 TWh were used by households and 2.6 TWh in the commerce, trade, service sector. Thus, district heating accounted for 8.43 % of the heat consumption of NRW [4]. Germany had a total district heat consumption of 114.1 TWh in 2017. This means, that NRW accounts for 23.14 % of the total German district heating consumption. It is noticeable that in Germany the majority of district heating (51.5 TWh) is consumed by households, closely followed by the industry (47.8 TWh). In NRW, however, the industrial sector has the largest consumption of district heating with more than 50 %. This is not surprising, since NRW and especially the Ruhr area is an industrial stronghold that has a high energy consumption.

The Ruhr area had a district heating consumption of approximately 7.53 TWh in 2017. This was estimated with the values of NRW.

Bochum, a city in the Ruhr region, can be taken as another example. In 2019 the end use energy consumption in Bochum was supplied by the following energy sources: the leading source was gas with an amount of 2190 GWh, followed by district heating with an amount of 522 GWh and heating oil with an amount of 432 GWh. Heat pumps (9 GWh), electric heating (47 GWh) and renewable sources (e.g. biomass; 57 GWh) play a minor part in Bochum.

The BDEW (Bundesverband für Energie- und Wasserwirtschaft) has examined the heating behavior of Germans in a recent study. In NRW there are 8.7 million apartments that are heated with various heating systems. The leading technology/energy source is natural gas. It is used to power 3.5 million (40%) central heating systems, 1.2 million (14.3%) floor heating systems and some gas heat pumps and gas stoves. A total of 4.8 million apartments in NRW use natural gas, which corresponds to a share of 55.6 %. Throughout Germany, 48.2% (19.5 million) apartments use natural gas. Heating with oil takes second place. Around 2.1 million (23.9%) apartments in NRW are heated with oil central heating and only 61000 (0.7%) with oil stoves. This results in a total share of 24.5 %. In Germany the share is 25.6% (10.4 million). In NRW district heating ranks third with 0.8 million (9.1%) apartments. In Germany, a total of 5.6 million (13.9%) apartments are supplied with district heating. This means that around 14% of all apartments in Germany that are supplied with district heating are located in NRW. The remaining apartments are heated with “other energy sources” such as liquid gas, wood and electricity. [5]

[1] Own calculation

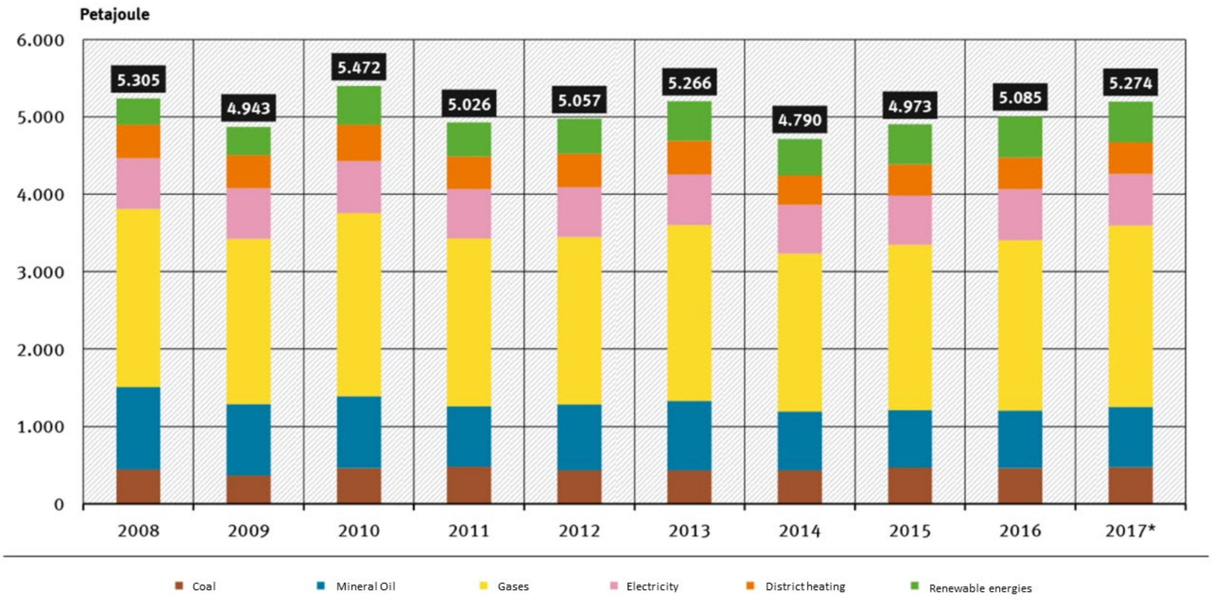

Figure 3: Heat consumption by energy source in Germany [6]

Figure 3 displays the heat consumption by energy source in Germany. The considered energy sources are coal (brown), mineral oil (blue), gas (yellow), electricity (pink), district heat (orange) and renewable energy (green). Each column represents one year. The share of district heat is a small but not unimportant part of the heat consumption and stayed at the same level over the past years. It also shows that gas is by far the most widely used energy source. In second place is the mineral oil. The distribution is similar to the energy sources that are used for heating in NRW.

According to AGFW (2018), NRW has 257 district heating grids that are operated with water. They have a length of 4981 km with an output of 9636 MW. Compared to Germany, this corresponds to 23.51 % (21184 km) of the nationwide district heating grid length and 19.30 % (49931 MW) of the nationwide district heating output. In addition, there are 9 steam powered district heating grids with a grid length of 102.4 km, which corresponds to a share of 18.55 % (551.9 km) of the nationwide steam powered grid, and an output of 860,8 MW, which corresponds to a share of 24.47 % (3532.4 MW) of the nationwide output. [8]

District heating is mainly generated by CHP and waste incineration plants, but also increasingly from decentralized heat sources such as industrial waste heat and renewable energies. Gas-fired and coal-fired power plants are of particular interest for CHP. However, the coal phase-out will take place by 2038 at the latest. Until then, alternatives must be used to supply district heating networks.

The district heating network (DHN) of the Ruhr area is one of the largest in Europe. It consists of five independents primary DHNs. They are furthermore separated in 25 secondary DHNs. The DHN delivers 6500 GWh per year with a maximum thermal power of 2300 MW. Feed and return flow temperatures vary. The primary networks of Fernwaermeversorgung Niederrhein GmbH and Steag operate at a maximum of 180 °C feed flow temperature, E.ON Nord and E.ON Sud (connected), Oberhausen, and Duisburg operate at a maximum of 130 °C. The secondary network only operates within the range of 100 °C to 110 °C, since it obtains the heat from the primary networks. The return flow temperatures are set between 60 °C and 70 °C. The following figure shows the district heating grid of the Ruhr area.

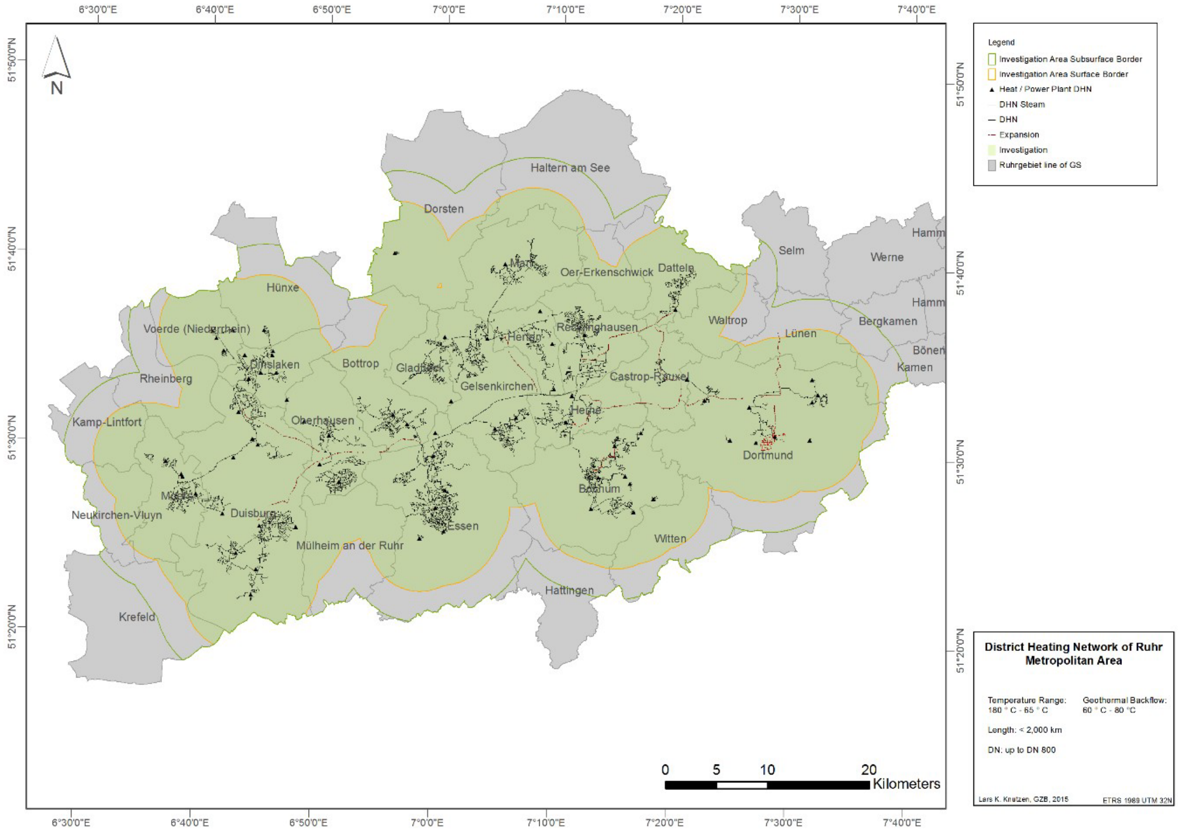

Figure 4: District heating grid of the Ruhr area [9]

District heating in the current heating regime

In order to achieve the goals of the planned heating transition by 2050, the proportion of conventional heating methods must decrease and be replaced by future-oriented methods. To this end, the expansion of combined heat and power (CHP) and district heating is being promoted. As already mentioned in 4.1.1, the share of district heating of the heat consumption in 2017 in NRW was around 8.43%. However, in 2015 the share of district heating of the final energy consumption was only 4.66 %.

The Ruhr area had a district heating consumption of approximately 7.53 TWh in 2017. This would mean that the Ruhr area accounts for about one third of the district heating consumption in NRW. This was estimated with the values of NRW.

Figure 6 displays the district heating consumption according to sectors and its share of the end energy consumption in NRW. Each column represents one year. The columns are divided into industry (light blue), household (dark blue) and commerce, trade, service– sector (light turquoise). The left y-axis indicates the amount of energy in TWh and refers to the bars. The right y-axis describes the share of district heating of the final energy consumption in percent and refers to the red line.

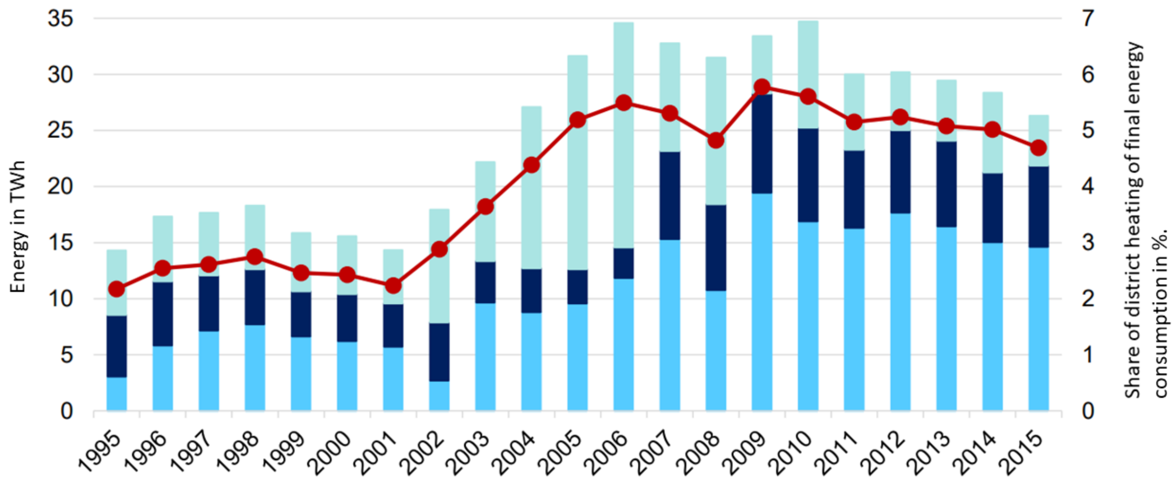

Figure 5: District heating consumption according to sectors and their share of end energy consumption in NRW [10]

Over the past 20 years, the share of district heating in the industry has grown from an initial 3.1 TWh/year to 14.6 TWh/year in 2015. The household sector also recorded an increase of 1.7 TWh in the same period (from 5,5 TWh to 7.2 TWh per year). Only for the commerce, trade, service-sector and other consumers did the district heat decrease from 5.8 TWh to 4.4 TWh per year. The total heat consumption from district heating grids in NRW increased by a factor of 1.8 during the period under review. Today the expansion of heating grids continues to be supported by laws and subsidies [10].

Main actors in the current heating regime

Natural gas is the second most important primary energy source in the German energy mix after mineral oil. In 2016, its share of primary energy consumption was 22.6 percent [11]. Most of the gas for energy supply in Germany is supplied to Germany from abroad. The gas network in Germany has a total length of 511 000 kilometres. In connection with the gas supply, companies operate in the areas of gas pipelines, distribution grid, storage and trade [12]. Gas trading is a big part of the heating market. The German gas market is characterized by a large number of market players organized under private law in the areas of gas networks, storage operation and trading. There are currently two market areas (NCG and Gaspool), each with a market area manager who ensures the efficient handling of gas network access and market operations [11].

There are currently 1050 gas suppliers and 16 gas transmission companies in Germany. Other players include distribution system operators, storage operators, and trading companies. The following figure shows important gas suppliers by gas sales in Germany in 2019. In 2019 the total gas sales amounted to 929 995 GWh. [13]

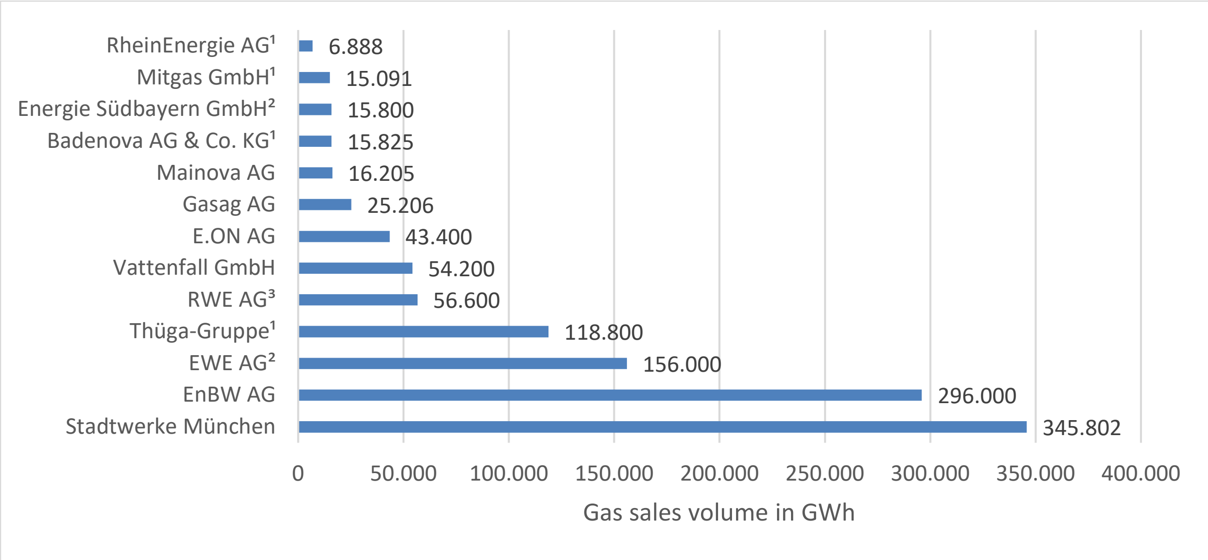

Figure 6: Important gas suppliers by gas sales in Germany in 2019 [13]

Stadtwerke München, EnBW AG, EWE AG and the Thüga Group have particularly high sales compared to the other companies. It should be noted that sales from Stadtwerke München include both natural gas and oil. The Thüga-Group consists of over 100 municipal utilities throughout Germany. Otherwise RWE AG, Vattenfall GmbH and E.ON AG play an important role in the gas market.

The district heating supply is dominated by large energy supply companies. However, municipal utilities are also often main actors. They act as producers, grid operators and traders at the same time. Thus, there are ten providers that control most of the district heating in the Ruhr area.

The main district heating operators in the Ruhr area are:

- DEW Dortmunder Energie- und Wasserversorgung GmbH
- ENNI Energie und Umwelt Niederrhein GmbH
- Uniper Wärme GmbH
- Energieversorgung Oberhausen AG
- Fernwärmeversorgung Herne GmbH
- Fernwärmeversorgung Niederrhein GmbH
- Hertener Stadtwerke
- Stadtwerke Bochum Gruppe (including FUW GmbH)
- Stadtwerke Duisburg GmbH
- STEAG Fernwärme GmbH

Legal framework and operational context for these actors

In the area of district heating, there is no regulated third-party access (TPA) in Germany. This is, among other things, due to the fact that district heating networks are self-contained local water- or steam-based supply systems where it is not readily possible to transfer the heat from external/third-party suppliers. District heating producers are usually also the owners and operators of district heating networks [14]. Additionally, there are several (unregulated) bilateral contracts between the owners/operators of district heating networks and heat suppliers (e.g. waste heat, waste incinerating plants). With regard to the design of district heating supply contracts, the Federal Ministry for Economic Affairs and Energy (BMWi) was authorized to design the general conditions for the supply of district heating of end customers. The BMWi has introduced such a regulation by decree of the AVBFernwärmeV [15]. For example, the AVBFernwärmeV stipulates that price change clauses may only be designed in such a way that they take account of both the cost development in the production and supply of district heating by the company and the respective conditions on the heat market. They must identify the relevant calculation factors in full and in a generally comprehensible manner to ensure price transparency for the customer [16].

In addition, there is no restriction on who may build or operate a district heating network. This is very helpful for the future implementation of further D2Grids projects.

The heating market is strongly influenced by the requirements of various laws aimed at reducing energy consumption in the building sector.

The Energieeinsparungsgesetz (EnEG) was introduced with the aim to reduce energy consumption in the building sector. It enables the federal government to regulate the following aspects with respect to the heat domain (§1-§2a) [17]:

- Energy efficient thermal insulation in new buildings to reduce loss of energy (§1(1))
- New installations of energy-saving systems in buildings (concerning new installations of heating, room air technology, cooling and water supply systems, etc. specifically in the course of retrofitting) (§2(1))
- Building standards: Buildings with heating or cooling systems that are constructed after 31st December of 2020 have to meet criteria as "lowest energy buildings" ("Niedrigstenergiehaus") (§2a (1))

More regulations and standards set by the Federal Government are formulated in the Energieeinsparverordnung (EnEV). It states that buildings must comply with several minimum energy and heating performance standards and addresses technical aspects for example the replacement of oil and gas boilers, thermal insulation of ceilings and top floors or the application of energy performance certificates. [17]

Another law relevant for the domain was the Erneuerbare-Energien-Wärmegesetz (EEWärmeG), which was passed to increase the share of renewable energies for heating and cooling in the building sector to 14 % until 2020.

The Gebäudeenergiegesetz (GEG) has come into effect on 01.11.2020 and merged the EnEG, EnEV and EEWärmeG into one modern law. The GEG creates a uniform, coordinated set of regulations for the energy requirements for new buildings, for existing buildings and for the use of renewable energies to supply heating and cooling to buildings.

These laws encourage the use of district heating. On one hand, there is an obligation to exchange oil and gas boilers that are more than 30 years old. This gives an impetus to switch to a district heating connection instead of installing a new boiler. On the other hand, there are requirements for new buildings to use a minimum share of renewable energies. However, these requirements can be met through alternative measures. This includes connection to district heating grids that draw at least 50% of the heat from CHP systems.

Current organization of heating markets

The German gas market has been officially liberalized since 1998, but significant progress in liberalization is only measurable since 2007. For this purpose, network access has been significantly simplified and the number of market areas has been reduced in various steps from 19 to officially two [18]. The German gas market is currently divided into two market areas, each with separate H-gas and L-gas trading. The so-called entry-exit-model is used. With the amendment to the Gas Network Access Ordinance (Gasnetzzugangsverordnung) 2017, the transmission system operators were obliged to create a uniform Germany-wide market area from the two previous market areas NetConnect Germany and GASPOOL by April 2022 at the latest. [19]

In contrast to the gas market, there is no regulated TPA in the district heating market. There is kind of a monopoly structure since district heating grids are typically self-contained water or steam-based supply systems. This means that the district heating suppliers are usually the only providers within the respective network area. Thereby no direct competition exists, and customers cannot choose freely between different district heating providers. There is also no wholesale market for district heating. [20]. Traditionally, district heating suppliers are vertically integrated companies, i.e. they operate the heat distribution network and supply heat, mostly self-generated, to the customers connected to the network. They are therefore active in several markets: on the market for the transport of heat over the grid, on the other hand on the markets for the supply to industrial/commercial customers, large redistributors or household and small business customers [14].

3.1.2. Developments in heating policy and market contexts

Current developments in the legal system and market organization

The transition from the Energieeinsparungsgesetz (EnEG), the Energieeinsparungsverordnung (EnEV) and the Erneuerbare-Energien-Wärmegesetz (EEWärmeG) to the Gebäudeenergiegesetz (GEG) is currently taking place. The GEG implements the coalition agreement, the resolutions of the "Wohngipfel 2018" and the measures for the 2030 climate protection program with regard to energy saving law for buildings. A uniform coordinated set of rules has been created for the energy requirements for new buildings, for existing buildings and for the use of renewable energies for heating and cooling buildings [21].

The CO2 tax on gasoline, diesel, heating oil and gas has been in force in Germany since January 2021. Previously, only companies in certain sectors had to pay for CO2 emissions. These included, for example, airlines or industrial companies that produce a large amount of the greenhouse gas. With a uniform CO2 price, Germany aims to achieve its CO2 reduction targets. Thus, anyone offering goods or services that emit CO2 will have to pay this tax.

Germany will phase out coal-fired power generation by 2038 at the latest, and preferably as early as 2035. The first power plants will be taken off the grid in 2020, and by the end of 2022 only 30 gigawatts of today's 40 gigawatts of coal-fired power plant capacity (15 gigawatts each of hard coal and lignite) will still be in operation; by 2030 only 17 gigawatts (8 gigawatts hard coal and 9 gigawatts lignite) will remain.

However, there are support measures. Federal funding for efficient heating grids (heating grid systems 4.0) is handled by the "Bundesamt für Wirtschaft und Ausfuhrkontrolle (BAFA)". This addresses innovative heating grid systems with a predominant share of renewable energies and waste heat. There are different funding modules. Feasibility studies can be supported with up to 60 % of the eligible expenditure. The implementation of a heating grid system 4.0 is subsidized with up to 50% of the eligible expenditure. However, this only applies to the construction of a new grid or the transformation of complete heating grid systems. Furthermore, it is possible that measures that aim to inform customers about the planned heating grid system are funded [22].

Expected developments in terms of energy transition policy or market transformations to accommodate green energy

The emissions in the heating sector remained the same between 2011 and 2017, because of the absence of a CO2 price. However, with CO2 certificates, incentives can be created to reduce CO2 emissions in a cost-effective manner using inexpensive technologies. This concept is already being used in the energy sector and industry, which enabled a reduction of 33.3 % respectively 31.0 % between 2005 and 2018 [23].

The CO2 pricing could be implemented in the form of a surcharge, based on the CO2 emissions, on the energy taxes of heating oil, natural gas, diesel and petrol. However, despite all the virulence of the current climate policy debate, it does not appear very likely that the building sector will be integrated into the European emissions trading soon [23].

From 2026 on, oil heating may not be installed at all or only as a hybrid system that integrates renewable energies. In addition, oil and gas boilers that are more than 30 years old must be replaced. A ban similar to that of oil heating is not foreseeable for gas heating. This can be attributed to the fact that the well-developed gas network would lose its usefulness.

In addition, there is a potential funding program by the Federal Ministry for Economic Affairs and Energy (Bundesministerium für Wirtschaft und Energie) called „funding for efficient heating networks" (Bundesförderung Effiziente Wärmenetze), which is expected to be passed in 2021. The Federal Association of Energy and Water Management (Bundesverband der Energie- und Wasserwirtschaft) is assuming that this funding program will be adopted in 2021 and that it will be of great importance for the implementation and advancement of the heating transition in Germany.

3.2. Position of district heating

3.2.1. Regulation of district heating providers and 5GDHC

No regulatory body exists for DH in Germany to regulate a TPA. However, DH is affected by most of the laws ruling the energy sector, which have significantly evolved during the last decade. Some of these laws incentivize DH by supporting CHP, energy efficiency or renewable energy requirements in buildings. However, price setting as well as the design of contracts, on the other hand, are regulated by law (e.g. AVBFernwärmeV). Compliance with these requirements is monitored by the Cartel Office (at federal or regional level). In this respect, also compare the remarks in the heading "What is the legal framework and context these actors are operating in?" and section 4.2.3.

3.2.2. Ownership and operation of district heating systems

District heating suppliers are usually vertically integrated companies. Production, grids and sales are in one hand. The main actors are the large energy providers, grid operators and technology plant manufactures. In the DH and CHP technology field, it is hence mainly a few large plant-manufacturing companies (such as Siemens) who are driving innovations. In general, most DH plant and grid operators are partially publicly owned and partially private companies. [17]

The municipalities are key players in the heating transition, in particular because of their diverse connections to end-consumer-groups. Municipalities award concessions for heating grids and operate their own heating grids and power plants through the municipal utilities, sometimes in cooperation with citizens' cooperatives. Municipalities also create long-term climate protection concepts and energy plans and can use their own properties. [24]

In addition, district heating grids mainly run under public traffic routes and land owned by the respective municipality. To be able to lay district heating pipes and operate them, a district heating supplier is dependent on the respective municipality allowing the use of these areas.

3.2.3. Regulation of the price setting

District heating suppliers are usually vertically integrated companies. Generation, grids and sales are in one hand and determine acting in the grid islands. Thus, there is no competition and without regulation the prices could be "freely" determined by the providers [20]. However, the prices of the gas and oil providers play an important role. If the price for district heating is too high, the customer can change his heating technology. Therefore, district heating providers have to adapt to the prices of gas, oil and other influencing factors such as CO_2 emission allowances.

With regard to the design of district heating supply contracts, the Federal Ministry for Economic Affairs and Energy (BMWi) was authorized to design the general conditions for the supply of district heating. The BMWi has introduced such a regulation by decree of the AVBFernwärmeV. For example, the AVBFernwärmeV stipulates that price change clauses may only be designed in such a way that they take account of both the cost development in the production and supply of district heating by the company and the respective conditions on the heat market. They must identify the relevant calculation factors in full and in a generally comprehensible manner to ensure price transparency for the customer. Compliance with this ordinance (AVBFernwärmeV) and further requirements is monitored by the German Federal Cartel Office and the cartel offices at regional level.

3.2.4. Role of building owners and building occupants

Deciding the heat source of the building

In single-family buildings, the building owner decides about the heat source. There are laws that influence the type of heat source. For example, in new buildings, a certain percentage of the annual heat must be covered by renewable energy. Occasionally, it is a desire of the municipalities to promote district heating by introducing a so-called connection and use obligation. But in practice, municipalities nowadays introduce a connection and use obligation less and less frequently.

If several people own shares in the building, the parties must come to an agreement.

Investments and energy bill

The building owner pays for the investment. If it is an energy improvement, the owner is entitled to increase the annual rent of the occupants by 8 % of the costs.

The energy bill is paid by the end user.

3.2.5. Financing and subsidies

Localized subsidy or grant mechanisms available

In order to increase efficiency in the area of electricity and heat generation, the Federal Government supports the expansion of combined heat and power, in particular through the “Kraft-Wärme-Kopplungs-Gesetz” (KWKG). In addition to the electricity remuneration for CHP systems and the promotion of heat and cold storage, the KWKG provides funding for heating and cooling grids. A maximum of 20 million euros can be paid out per project, as long as the supply of consumers connected to the new or expanded heating grid is at least 75 percent from CHP heat. Alternatively, other heat mixes are also possible [25].

With the Market Incentive Program (MAP), the Federal Ministry for Economic Affairs and Energy (BMWi) offers subsidies for companies. Funding for the expansion or new construction of local heating networks is particularly interesting for large companies, provided that a certain proportion of heat distributed in the company is generated with renewable energies. Heating grids that are powered from renewable energies can receive a repayment subsidy of up to 1 million euros. If geothermal energy is used, this can even increase up to 1.5 million euros [26].

Municipalities can also benefit from the BMWi’s market incentive program. The construction and expansion of heating grids are funded if they are powered by renewable energy. The term of the loan can be set variably up to 30 years, usually for up to 25 million euros per project. Up to 100 % of the eligible costs are financed [26].

See also description of funding programs under point 4.1.2. (Developments in heating policy and market contexts).

3.3. Available energy sources and storage

For the development of 5GDHC, it is important that each region gains insights in other (possibly low temperature) heat sources which are available today or in the future. As part of the work in D2Grids, a preference scale of energy sources has been developed (see D.T1.1.4 generic 5G technology model). The structure of this section reflects this ranking, with the highest-ranking forms of energy mentioned first. These sources are in most cases not only relevant for 5GDHC development. When there are many high or medium temperature sources available in a region, the case of 4GDH might be better than for 5GDHC. Currently, we have no way of quantitatively saying what the shares of low-grade sources would be in order to make a decent 5GDHC business case. At the time of writing, D.T1.1.4 has not been finalized.

Depending on the region and the country, there are different energy sources and storages. This can mostly be attributed to the different topography and available natural resources. For the development of 5GDHC it is relevant to know the different energy sources and storages. This allows planning from which source energy is to be drawn or whether another grid variant/generation such as 4GDHC is more advantageous. The focus is on renewable energies. However, the potential of fossil fuels is also considered.

The existing energy sources and storages in the Ruhr area can be estimated well. The reason for this are the diverse potential studies of the "State Office for Nature, Environment and Consumer Protection North Rhine-Westphalia“ (Landesamt für Natur, Umwelt und Verbraucherschutz Nordrhein-Westfalen (LANUV)). Much of this information is entered in energy atlases and potential maps to provide easy access. For example, in the field of geothermal energy, the potential map of NRW can be accessed to check the productivity of geothermal probes. For the potential of mine water, the potential study “Warmes Grubenwasser” of the LANUV can be accessed. Furthermore, the use of old mine buildings as storage facilities is possible in the Ruhr area, which is an advantage over many other regions. As shown a lot of information is available via the NRW energy atlas.

This enables a summary of the energy sources and storages that are of interest for the implementation of 5GDHC. This is also particularly interesting for the implementation of further 5GDHC in the future. The list of the following subsections reflects the relevance of the forms of energy for 5GDHC, whereby the most important form of energy is mentioned first.

3.3.1. Reuse of thermal energy, by exchange between heating and cooling demands

There is a great potential and a wide range of possible applications, but at the moment there are almost no figures or studies. There is only some minor talk about the advantages of the exchange between heating and cooling demands, which are represented in the following text.

Simultaneous cooling and heating is a requirement that often comes into play, particularly in larger commercial buildings, offices, shops and property construction. In one part of the building, heat must be dissipated (e.g. server room), while in another area, heating or hot water is required. An exchange between the superfluous and the required energy can take place here by means of appropriate systems.

Heating and cooling are also important issues in industry. More than 70 % of the final energy consumption in the industry is used for heating and cooling, the largest part of which is process heat. For this purpose, case studies were carried out in the research project “EnPro”, which examined the use of heat pumps to shift heat and cold. The active cooling of industrial processes has received little attention as an efficiency potential so far. The BAT document on energy efficiency states that cooling should be combined with the use of heat, otherwise it would be wasteful. In all cases considered, the end and primary energy consumption and CO2 emissions are reduced. Therefore, the integration of a heat pump and thus the combined use of heat and cold leads to an increase in efficiency and a reduction in emissions [27].

3.3.2. Ambient thermal sources from soil, water, air, and low temperature solar heat

Warm mine water [28]

The closure of mines does not mean that the use of the underground mine tunnels and pits has to end. Mine water contains an energetic heat potential, which was investigated by the LANUV in a potential study.

It is possible to use the regional heat potential from warm mine water from former and still operating mining infrastructure in NRW. For this purpose, the LANUV limited the determination of the potential to areas in which the warm mine water occurs or is still accessible through an existing infrastructure. In NRW this concerns:

- The closed stone coal strip mines with
  - Drainage systems (pump stations)
  - Former mine shafts

Open systems have a mine water temperature of a maximum of 35 °C.

Table 1 shows the technical heating energy that can be obtained in the Ruhr area either by means of dewatering or sump measures or from mine shafts. The year 2035 was chosen as the reference year.

Table 1: Heating potential of mine water in the Ruhr area (2018) [29]

	Technical heating energy (MWh/a) (Reference year 2035)	
	Drainage	Mine shaft
Bochum	212424	1163.4
Bottrop	0	2728.7
Dortmund	0	3798.8
Duisburg	137510	412,3
Ennepe-Ruhr-Kreis	0	0
Essen	190253	3842.8
Gelsenkirchen	0	10614.1
Hagen	0	0
Hamm	0	4584.4
Herne	0	1539.1
Mühlheim an der Ruhr	0	0
Oberhausen	0	2742
Recklinghausen	0	26030.6
Unna	141564	10889
Wesel	729511	5575.2
Total	1411262	73920.4

Shallow geothermal energy [30]

Large amounts of energy are stored in the earth and new energy is constantly being produced. The use of geothermal energy in the upper 400 meters is called “shallow geothermal energy”.

NRW has a geothermal potential of 153.7 [TWh/year]. This is limited to shallow geothermal energy (up to 100 m) and geothermal probes. The heat requirement is 271.1 [TWh/year], which would allow a coverage of 56.7% by means of geothermal energy.

The graphic below shows the technically usable geothermal potential for each district.

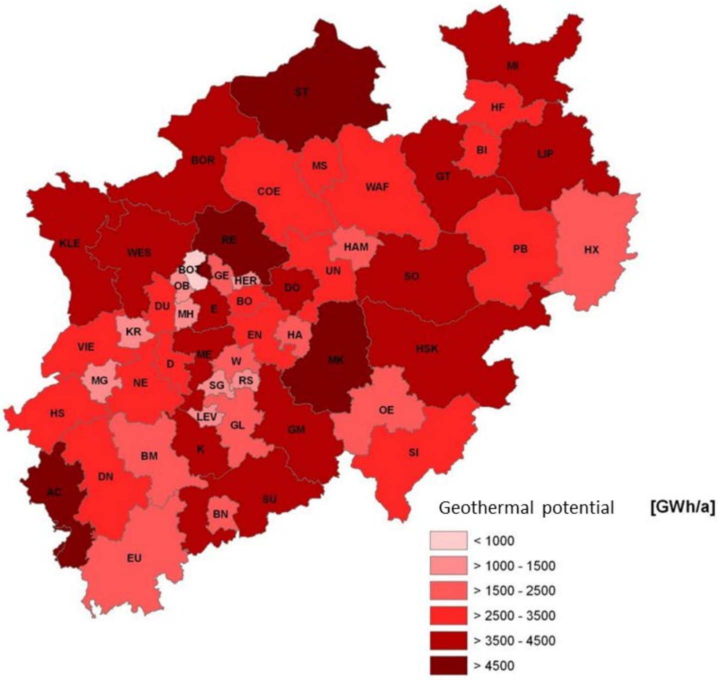

Figure 7: Potential of shallow geothermal energy in NRW (2015) [30]

The exact geothermal potentials in two scenarios of the Ruhr area are shown in Table 2.

Table 2: Geothermal potential of the districts and independent cities in the Ruhr area (2015) [29]

	Technical potential (GWh/a)	
	Scenario A	Scenario B
Bochum	2853.9	2806.3
Bottrop	918.3	851.4
Dortmund	3671.7	3602.4
Duisburg	3192.0	3062.2
Ennepe-Ruhr-Kreis	3470.0	3194.5
Essen	4248.1	4196.7
Gelsenkirchen	1775.3	1769.5
Hagen	1527.8	1485.9
Hamm	1631.5	1631.5
Herne	1128.6	1128.6
Mühlheim an der Ruhr	1312.5	1218.3
Oberhausen	1456.4	1456.4
Recklinghausen	5182.0	4958.8
Unna	3350.2	2980.2
Wesel	4252.6	3760.5
Total	39970.9	38103.2

Due to an inhomogeneous approval practice regarding the limitation of use in hydrogeological critical areas and water protection zones, two scenarios were considered: Scenario A with a depth limitation of 40 m and water as brine liquid and Scenario B with a complete exclusion of use.

The highest potential is in Recklinghausen with 5182.0 (GWh/a) and the lowest in Bottrop with 919.3 (GWh/a).

3.3.3. Higher temperature renewable sources like geothermal, solar heat

Deep geothermal energy

Deep geothermal energy is the use of geothermal energy at depths between 400-5000 meters. Compared to shallow geothermal energy, the temperatures are much higher.

Two geological aspects can be identified for deep geothermal development:

- Thickness >> 100 m
- Widespread over the Ruhr area.

The following figure shows the geothermal potential for the formation "Kulm / Kohlenkalk". The temperature of the potential is over 80° C.

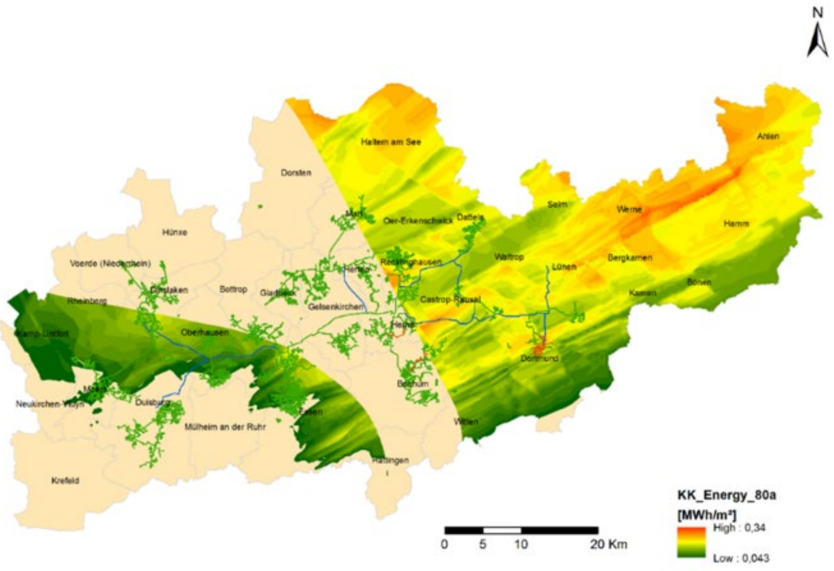

Figure 8: Geothermal potential of the formation "Kulm / Kohlenkalk" in NRW [9]

The geothermal potential for the mass limestone formation is shown in the figure below. The temperature of the potential is over 80° C.

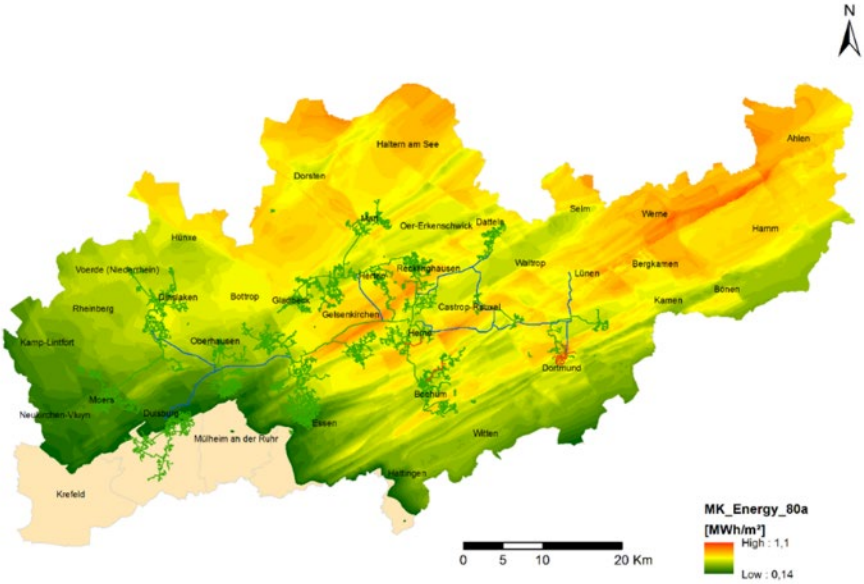

Figure 9: Geothermal potential of the formation "Massenkalk" in NRW [9]

Figure 10 and 11 show that the geothermal potential for the formation “Kulm / Kohlenkalk” as well as for the formation “Massenkalk” is the highest in the north of the Ruhr area and decreases more and more towards the south.

Solar thermal energy [31]

Solar thermal refers to the use of solar energy with the help of solar collectors for the provision of heating and hot water. In this way, the enormous energy potential of the sun can be used and fossil fuels and thus heating costs can be saved.

In 2016, more than 570 GWh of heat was generated with an area of about 1.5 km^2 of solar thermal collectors in NRW. Bochum has a solar thermal potential for heating water of > 50-100 (GWh/a).

In NRW, the theoretically producible amount of heat by means of solar thermal energy is 214.9 [TWh/year]. In the Ruhr area the production of 45.1 [TWh/year] of heat is theoretically possible. The annual growth rate in solar thermal energy has been at a relatively low and consistent level since 2010. The following figure provides an overview of the distribution of usable solar thermal energy potentials at the district level.

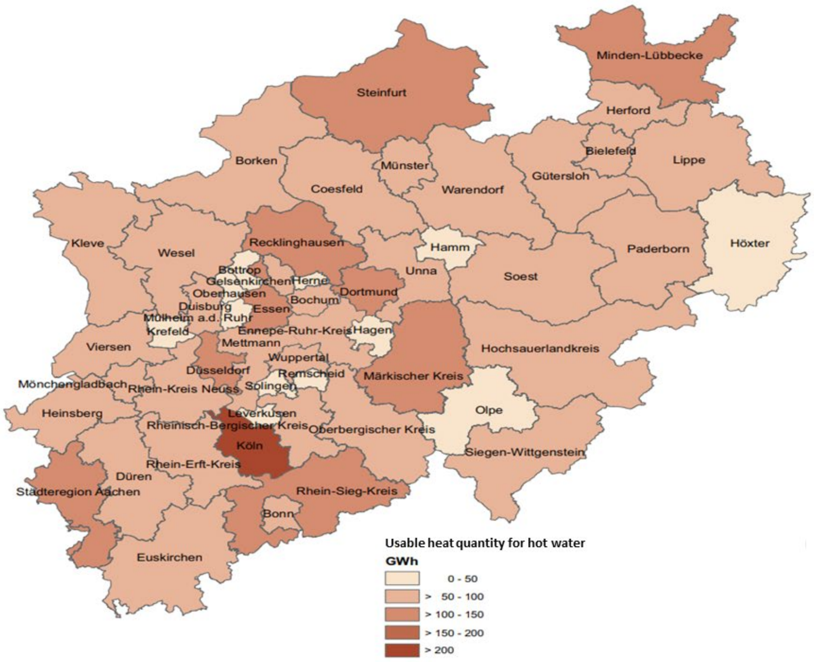

Figure 10: Solar thermal potential in NRW (2018) [32]

Table 3 shows the solar thermal potential of the districts and district-free cities in the Ruhr area. Essen has the highest potential with 138 (GWh/a) and Bottrop has the lowest potential with 24 [GWh/a].

Table 3: Solar thermal potential of the Ruhr area (2018) [29]

	Usable amount of heat for hot water processing (GWh/a)
Bochum	69
Bottrop	24
Dortmund	111
Duisburg	99
Ennepe-Ruhr-Kreis	89
Essen	138
Gelsenkirchen	53
Hagen	47
Hamm	39
Herne	35
Mühlheim an der Ruhr	33
Oberhausen	42
Recklinghausen	141
Unna	93
Wesel	99
Total	1112

3.3.4. Higher temperature industrial waste heat, otherwise rejected in the environment

In Germany, heat is the most important process energy for the industry. A secure energy supply is one of the most important location factors and decisive for the profitability of a company and the attractiveness of a region. More than one third of the process energy used in industry is lost globally as waste heat. The reuse of waste heat is therefore a necessary step, both from an economic perspective and in terms of sustainability. [10]

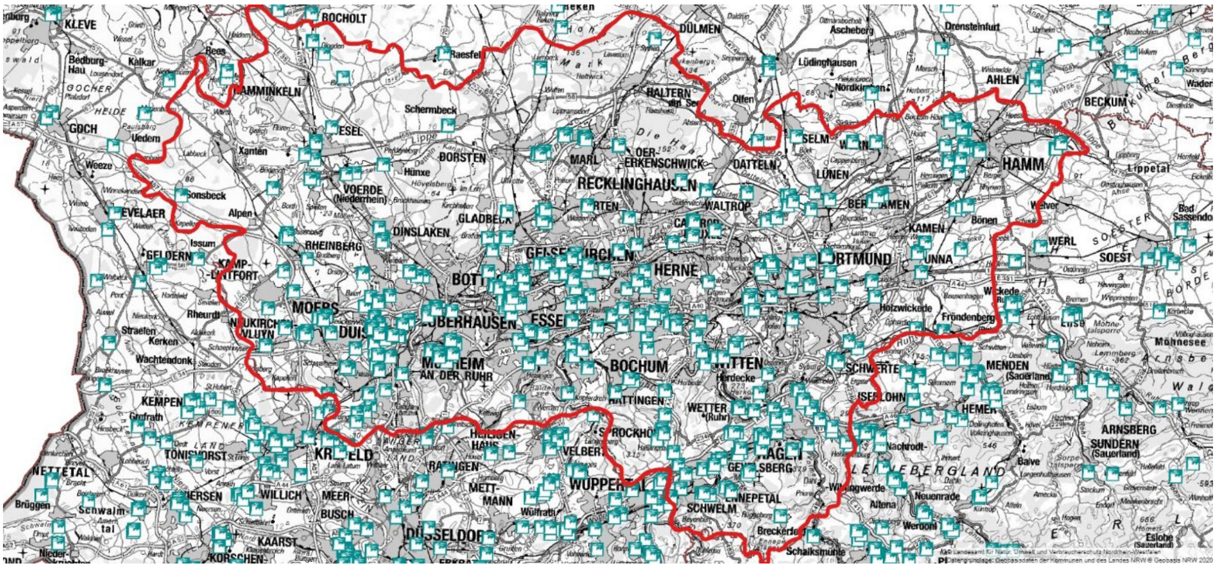

Figure 11: Locations of industrial companies with waste heat [33]

Figure 13 shows the locations of industrial companies that were classified as “potentially relevant for waste heat” in the industrial waste heat study in NRW. It can be recognized that a very large number of locations in the Ruhr area can deliver waste heat. The north-eastern part has a lower density of locations compared to the core or south of the Ruhr area.

In total there is a technically usable waste heat potential of approximately 44 – 48 [TWh/year] in NRW.

In figure 14, the Ruhr area is circled with a red line. The waste heat potentials of the industrial sites in the districts and district-free cities in NRW were aggregated in figure 14. Duisburg and the Rhein-Erft-Kreis represent the highest waste heat potentials with 2.1 [TWh/year] (18%) and 1.4 [TWh/year] (12%) at the county level. The lowest potential is in Remscheid. The following table shows the waste heat potential for the Ruhr area. [10]

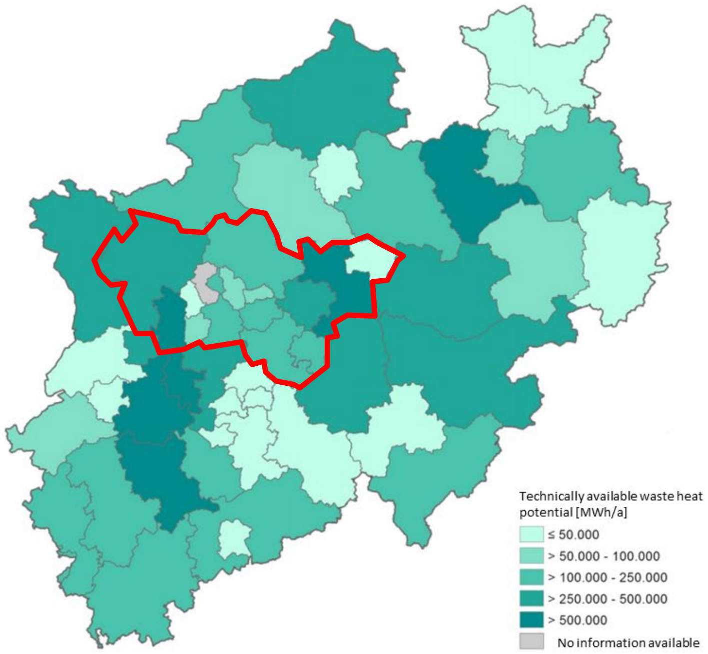

Figure 12: Potential of waste heat in NRW (2019) [10]

Table 4: Waste heat potential of the districts and independent cities in the Ruhr area (2019) [29]

	Technically available waste heat (GWh/a)
Bochum	134.1
Bottrop	0
Dortmund	313.7
Duisburg	2146.5
Ennepe-Ruhr-Kreis	107.9
Essen	158.8
Gelsenkirchen	99.3
Hagen	200.6
Hamm	14.2
Herne	51.5
Mühlheim an der Ruhr	75.9
Oberhausen	16.3
Recklinghausen	152.5
Unna	708.0
Wesel	267.4
Total	4446.7

3.3.5. Renewable electricity from local sources like wind, sun

Within the borders of NRW, 19774 GWh of electricity was generated by renewable energies (2017). 8855 GWh were generated by wind energy, 3556 GWh by photovoltaics (roof) and 6202 GWh by biomass. The rest was produced by other energy sources such as hydropower and mine, landfill and sewage gas. This represents 12.6% of the electricity generation. [34]

Exact values are not available for the Ruhr area.

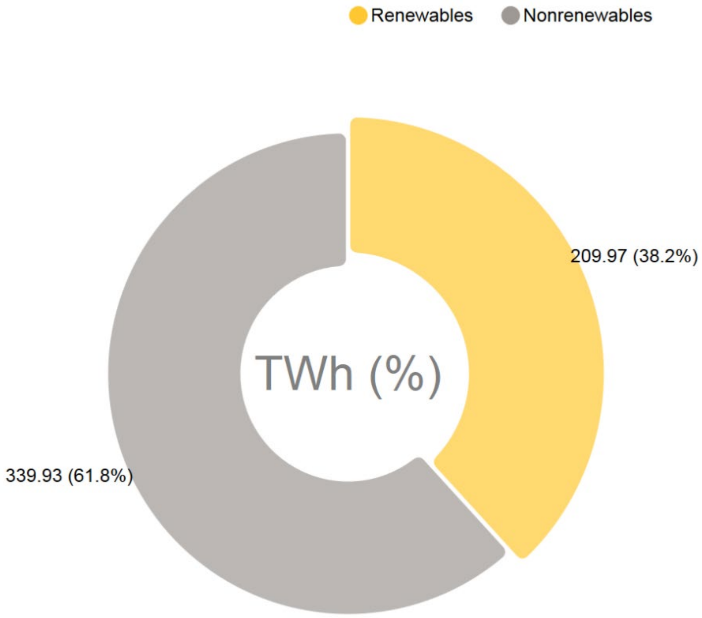

Figure 13: Total net electricity generation in Germany (2017) [35]

As can be seen in Figure 15, the share of renewable energy (yellow) in Germany in 2017 was 38.2 %. This means that the share of renewable energy sources in electricity generation in Germany is almost three times as high as in NRW. The reason for this is the high proportion of lignite used for electricity generation and the high population density in NRW. However, NRW has the potential to generate 46.7 GW_P with photovoltaic modules if all suitable roof surfaces in NRW are filled with modules. This could generate an annual electricity yield of 38.7 TWh. [31]

3.3.6. Electricity use at times of renewable overproduction, e.g. when spot price is low

For now, this is only relevant in areas with known overproduction, like the north of the Netherlands (overproduction of PV) and the north of Germany (wind).

3.3.7. Electricity mix from the external grid

Germany generated 515.56 TWh electricity in 2019 [35]. The electricity mix consists of:

- Nuclear: 71.09 TWh (13.8%)
- Brown coal: 102.18 TWh (19.7%)
- Hard coal: 48.69 TWh (9.4 %)
- Natural gas: 54.05 TWh (10.5 %)
- Renewables: 237.41 TWh (46.1 %)

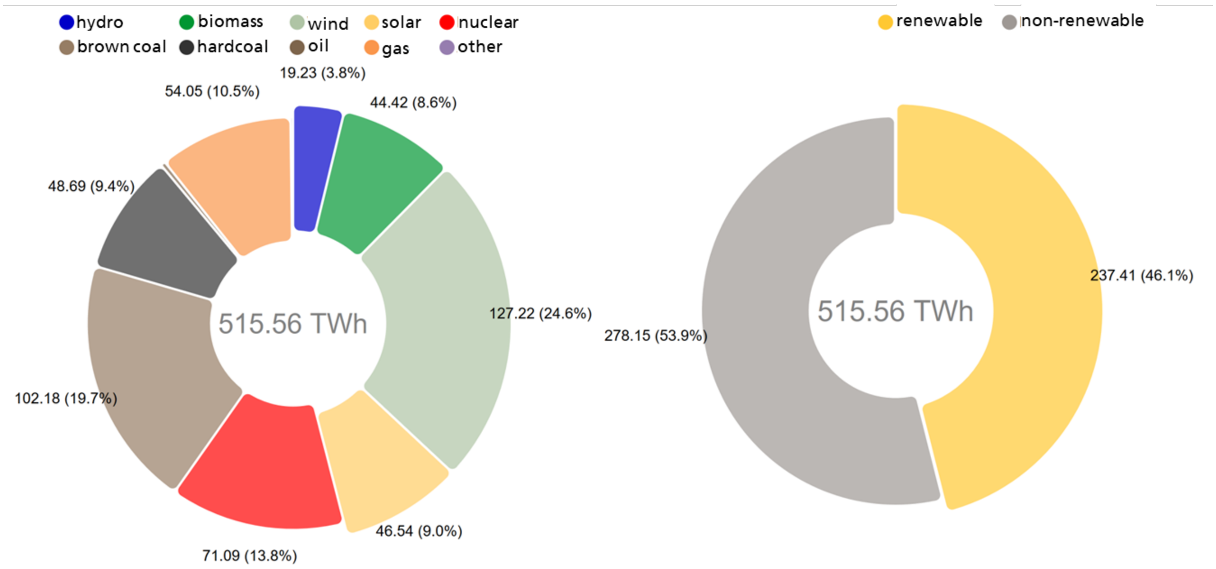

Figure 14: Net electricity generation in Germany in 2019 [35]

3.3.8. High temperature heat from burning biofuels, biogas, biomass

Figure 17 presents the biomass plants of the Ruhr area. It can be clearly seen that biomass plants are operating in the entire Ruhr area. There are over 100 biomass plants in total.

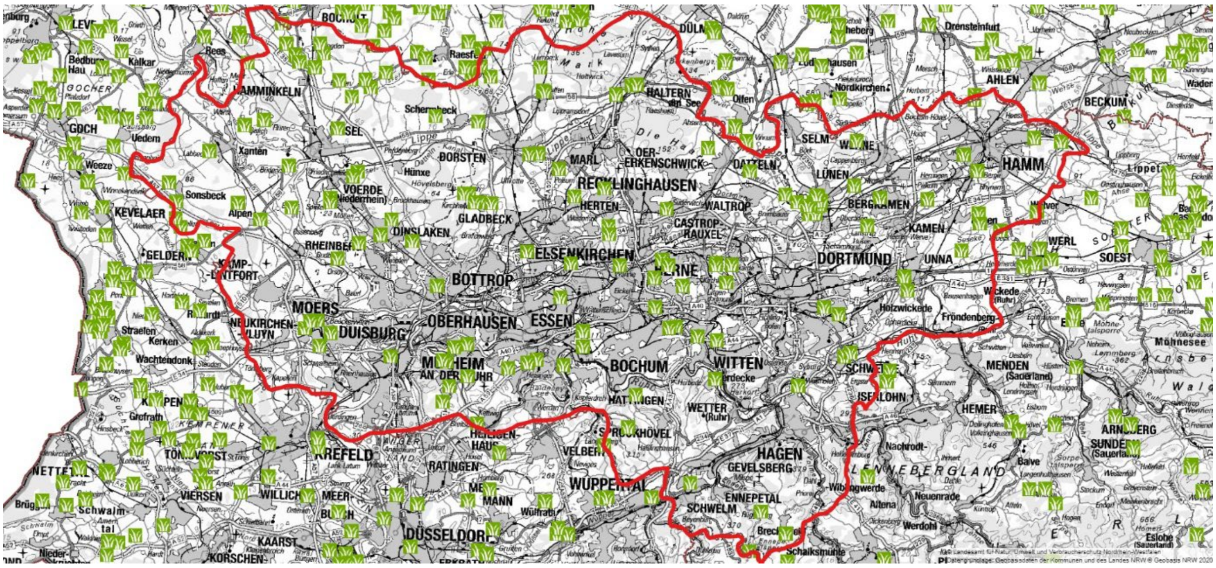

Figure 15: Biomass plants in the Ruhr area [34]

In addition, the potential of energy from biomass was researched. The minimum and maximum feasible potentials as well as the potentials of the NRW lead scenario were compared with the electricity and heat produced by biomass today. It shows that especially agriculture has the possibility of generating a large amount of heat with biomass [36].

Table 5: Potential of biomass of the sectors Landwirtschaft (agriculture), Forstwirtschaft (forestry) and Abfallwirtschaft (waste industry) in NRW (2014) [36]

Sector	Electricity [TWh/year]			Heat [TWh/year]			Already produced [TWh/year]	
	Minimal	Reference value	Maximal	Minimal	Reference value	Maximal	Electricity	Heat
Agriculture	2.60	4.65	9.57	11.36	12.00	15.64	1.41	1.75
Forestry	0.16	0.16	0.22	3.25	4.25	5.53	0.15	3.03
Waste Management	2.9	3.54	3.54	6.30	7.27	7.27	3.09	6.17
Sum	**5.66**	**8.35**	**13.33**	**20.91**	**23.52**	**28.44**	**4.65**	**10.94**

3.3.9. High temperature heat from burning fossil fuels

CHPs can generate mechanical energy and usable heat at the same time in a joint process. There are already some power plants in NRW that use combined heat and power [37]:

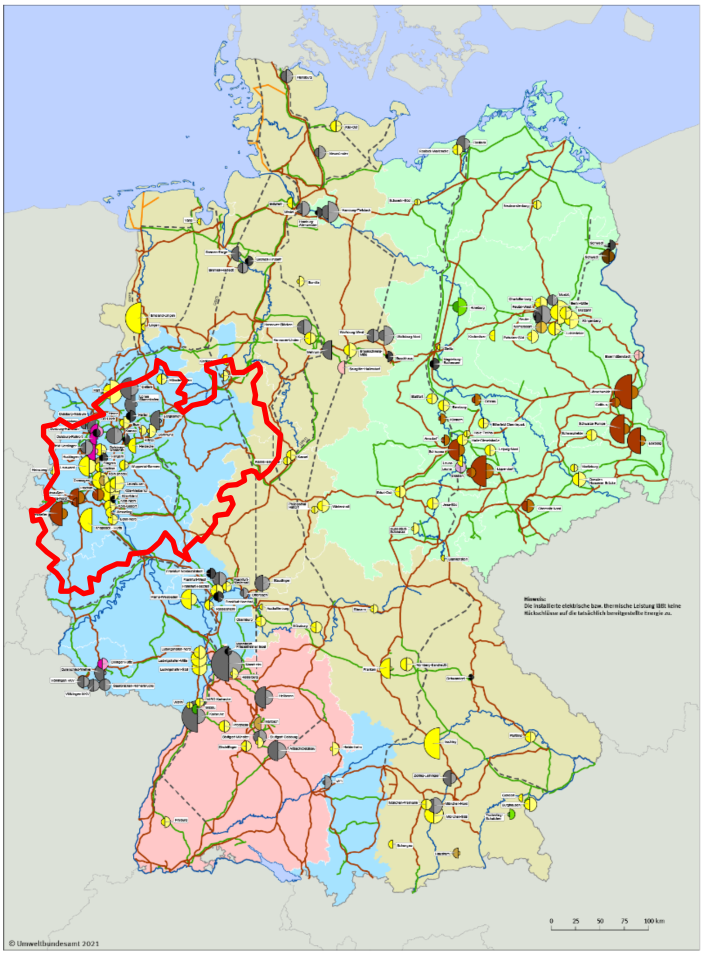

Figure 16: Power plants with CHP in Germany [38] (2020)

Figure 19 represents power plants with CHP in Germany, which have at least a capacity of 50 MW_{el} or 100 MW_{th}. NRW is located in the center of the west of Germany (red circled). It can be clearly seen that many power plants use CHP in NRW. Thus, there is a very good possibility to obtain heat from power plants in NRW. Overall, hard coal and gas plants are the most common. But there are also some lignite power plants, furnace plants power plants and waste power plants, which use CHP.

3.3.10. Low grade thermal storage possibilities

Low grade thermal storage is possible with flooded underground infrastructure, natural aquifers and artificial aquifers. But these storages aren't usable in every region. In the following the possibilities/potentials in the Ruhr area are considered.

There is the possibility of using the mine water in many mines in the Ruhr area to store heat. For the establishment of such underground thermal storage facilities, appropriate infrastructure measures must be carried out in the mine and suitable access and conveying systems must be developed. HEATSTORE is a project, which aims to accelerate the implementation of geothermal energy by promoting various types of underground heat storage facilities (UTES), providing a means to maximise geothermal heat production and addressing technical, economic, environmental, regulatory and political aspects, necessary to support the efficient and cost-effective use of UTES technologies in Europe.

Aquifer Thermal Energy Storage (ATES) is a suitable technique to supply buildings with large amounts of heating and cooling. ATES bridges the seasonal mismatch between the ambient temperature and the heating or cooling demand of a building. At the moment only four ATES exist in Germany. [39]

Borehole Thermal Energy Storage (BTES) use the underground rock to store heat. Geothermal probes are inserted up to 100 m deep into the ground in vertical or inclined boreholes. The heated water is led through these geothermal probes into the subsoil, where it heats the rock. Every shallow geothermal system can basically be used as a storage facility.

4. SWOT analysis

Given the information gathered above on the market and on availability of energy resources, an analysis of the strengths, weaknesses, opportunities and threats when implementing 5GDHC in the region can be made. The SWOT analysis will help to interpret the information given earlier and will as such help to understand which locations might be better suited for 5GDHC.

4.1. Strengths

4.1.1. Many unused mine structures

The Ruhr region has many disused mines and mine shafts. The existing warm mine water can be used as an energy source for 5GDHC. With its low temperature level of 13 °C - 35 °C it is perfectly suitable to supply low-temperature networks with temperatures of 50 °C.

4.1.2. Intercommunal cooperation

Intercommunal cooperation refers to the cooperation of municipalities, cities belonging to or independent of districts, as well as districts for the realization of common goals and tasks. Important task areas of intercommunal cooperation are in the field of spatial planning, technical infrastructure and environmental protection. 5GDHC is particularly dependent on other systems to function successfully. Through the joint implementation of such a project, the combination of the different systems can be secured.

4.1.3. High waste heat potential due to industrial structure

In Germany, heat is the most important process energy for the industry. Due to the dense industrial structure in the Ruhr area, there is a high production of waste heat. This waste heat potential can act as an energy source for 5GHDC. 4.4 TWh/year would be technically usable.

4.1.4. Densely populated area

With its 1152 inhabitants/km^2, the Ruhr region is one of the most densely populated areas in Europe. This plays into 5GHDC's cards, as many heat consumers live in a small area. This leads to reduced heat losses due to transport.

4.1.5. High potential for geothermal probes

In the Ruhr area, there is a high geothermal potential, especially for borehole heat exchangers. This is already being used by many private households and forms a good basis as an energy source for 5GDHC.

4.2. Weaknesses

4.2.1. Already existing high temperature district heating network

District heating networks already exist within the Ruhr area. However, these are operated with a high temperature level of 130 °C - 180 °C. This makes it impossible to combine the existing networks with 5GHDC. This means that certain areas cannot be developed for 5GDHC.

4.2.2. High proportion of old buildings

In the Ruhr region, 73 % of buildings were built before 1979. The energy demand of these buildings is correspondingly high because they are not well insulated. At the same time, the old radiators require very high flow temperatures. This contradicts the low flow temperature of 5GDHC.

4.2.3. Lack of sample projects as examples

Since this is a pilot project, there are no comparable projects from which information, improvements or assistance can be drawn. This is always a deterrent for stakeholders, as it means an uncertain investment.

4.2.4. Huge variety of independent district heating suppliers

Within the Ruhr region alone, there are 10 different district heating operators running their own networks. This means that the barrier to market entry is particularly high and it is difficult to find a firm foothold in the market. It will therefore be difficult to implement 5GHDC.

4.3. Threats

4.3.1. Waste heat will dissipate as a result of structural changes

The above-mentioned strength of the high potential of waste heat will decrease more and more in the future. This can be attributed to the coming structural changes due to climate targets. Industrial plants have to become more and more energy efficient and at the same time the operation of power plants will be discontinued. Waste heat currently functions as a good energy source, but it will become increasingly scarce in the coming decades.

4.3.2. Low prices for gas and no prospect of improvement

More than half of the apartments in NRW use natural gas. Due to the low gas prices, many building owners choose gas heating or do not consider switching to district heating. Moreover, there is no prospect of gas prices rising in the near future.

4.3.3. Future regulation of the district heating market

The district heating market is not currently regulated like the gas or electricity market. However, it is repeatedly stated that regulation of the district heating market is important and must come about. There are no firm plans for this, but there are various ideas ranging from network access regulation to regulation of the overall district heating price. Changes in the district heating market are therefore to be expected in the future.

4.4. Opportunities

4.4.1. Many different funding opportunities

There are many funding opportunities in the field of renewable energies. District heating is also supported, for example, by the BAFA's "Wärmenetze 4.0" (Heat networks 4.0) model or, in the future, by the Federal Ministry of Economics and Technology's "Bundesförderung effizienter Wärmenetze" (Federal funding for efficient heating networks) investment support program. At the same time, measures are promoted that lead to an increase in the energy efficiency of a building or the connection to a heating network. This promotes the use of district heating.

4.4.2. Pressure to act due to climate targets

The use of district heating will also become increasingly relevant in the future, as the climate targets set by Germany are to be met by 2030 and 2050. For example, the building sector is to emit only 70-72 million metric tons of CO2 equivalents (direct emissions) by 2030 - a reduction of 66-67 percent compared with 1990. Major efforts are needed in the building sector to achieve this very ambitious target.

For this, classic heating technologies such as gas and oil must be left behind and climate-neutral methods such as district heating in combination with renewable energies must be resorted to. Here, 5GDHC in particular can play an important role, as it accesses environmental energy for heating.

4.4.3. Extensive experience with heat pumps

Germany has expertise in the use of heat pumps. Due to the legal regulations for new buildings, a certain proportion of the heat consumption must be covered by renewable energies. For this purpose, many people resort to heat pumps. In 2020 alone, 120000 heat pumps were installed, which corresponds to a growth of 40% compared to last year.

5. Regional vision

5.1. High potential areas and potential pilot sites

There is a great difficulty in determining concrete possible future project areas for the Ruhr area and deducing the corresponding potentials. There are no uniform or general area development plans for the Ruhr area. The huge variety of independent district heating suppliers in the Ruhr area is a challenging aspect in terms of a further roll-out of 5GDHC in the region. Nevertheless, as the previous chapters show, there are good conditions and potentials for a further roll-out of 5GDHC technology in the Ruhr area. In addition, it can be assumed that the successful completion of the pilot project in Bochum on the Mark 51° 7 site can serve as a model and inspiration with enormous radiance for further projects in the region. However, it should be pointed out once again that the authorities/competences of the Bochum project partners in order to stimulate and plan follow-up projects in other parts of the Ruhr area are severely limited.

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