DISTRICT HEATING SYSTEM OF BERLIN; ITS PAST, CHALLENGES, and ECOLOGY

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District Heating System of Berlin

Basic Data for Berlin

City of Berlin, capital of Germany, has an area of 891 km^2 with an urban population of 3.7 million people. On average 4086 inhabitants per km^2 resides in Berlin, making it a densely populated city compared to Germany average which is 246 inhabitants per km^2 (Wikipedia, 2021). The climate is described as oceanic per Köppen classification, with winter temperature averages varying between 3 °C to -2 °C which are slightly warmer than Hamburg, and with a precipitation value of 669mm per year, approximately 20% less than Hamburg (meteodb, 2021). According to 2017 statistics, 52.4% of the population are living in single-person households and average living floor space per dwelling is 73 m^2 (ASBB, 2018b). GDP of Berlin has been €145b in 2018 which made up 4% of national total. On the other hand, growth rate was 4.42% between 2008 and 2018, a higher value in comparison to national level which is 3.54% (European Commission). Each Berlin inhabitant uses approximately 115 litres of water per day (ASBB, 2021b) and creates 372 kg of waste per year (ASBB, 2018a). Final energy consumption per inhabitant in Berlin in 2017 was around 18 MWh per annum and CO_2 emission per capita was 4.6 t/a. (ASBB, 2021a).

District Heating System in Berlin

Berlin's district heating history spans almost a hundred years. In 1926, Bewag (Berliner Städtische Elektrizitätswerke Aktiengesellschaft) started supplying 33 buildings with hot water and steam from Charlottenburg power station for the first time (Moss, 2020). In the following years, methane gas recovered from sewage treatment plants were started to be used as a fuel in district heating (DH) networks. During the division years, DH networks have faced different challenges in West and East Berlin, such as lack of maintenance or highly inefficient heating plants and distribution networks in the East or being on the target of criticism due to air pollution or other adverse environmental effects caused by plants in the West. After the reunification of Germany in 1990, DH network of East Berlin has been taken over by Bewag, which then transformed into Vattenfall during 2000s. After 2010, there has been challenges in court about who should own the network, Vattenfall or Berlin Energie, a municipal company. The result was in favour of Vattenfall but debates are still ongoing (Moss, 2020).

During the division years, DH networks have differed on two sides of the city in terms of technical infrastructure, and this remains to this day. For insular West Berlin, it was important to have DH networks as an alternative to coal-fired heating, through CHP plants to have less dependency to the East. In contrast to this, cogeneration was not used in East Berlin and heat was produced only in heating plants (Moss, 2020).

Berlin has the largest DH network in Germany with a total length of 2000km and 10.7 TWh heating capacity per year with Vattenfall being the largest operator. It supplies the 90% of DH demand to around 1.3 million households out of 2 million in total. Figure-1 shows important DH operators in Berlin. DH networks in Berlin use predominantly coal (45%) and natural gas (45%) as energy sources (Gonzalez-Salazar et al., 2020).

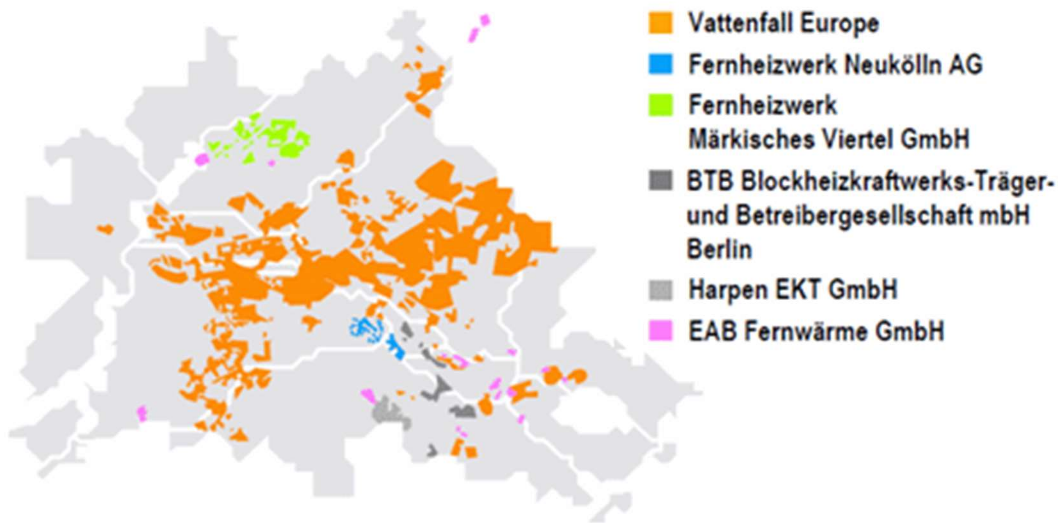

Figure 1-District Heating Operators in Berlin (Umweltatlas Berlin, 2010)

Challenges for District Heating in Berlin

City of Berlin has the goal to become climate-neutral by 2050 at latest, which means reducing GHG emissions by 95% in comparison to 1990 values (Gonzalez-Salazar et al., 2020). DH corresponds to one third (10.7 TWh pa) of the heating demand in the city. In 2017, three coal powered CHP plants in the city has caused 18% of Berlin's CO^2 emissions. Therefore, DH systems comprises an important role in the decarbonized future targets.

In 2020, German government has decided to phase out from coal by 2038 whereas in Berlin the process had already started earlier. Berlin Energy Turnaround Act which sets a framework for climate targets and policies came into force in 2016 (Berlin SenUVK, n.d.). As a result, steam generators which use lignite in Klingenberg cogeneration plant were decommissioned in 2017 (Gonzalez-Salazar et al., 2020). However, DH companies need to make more radical changes in their systems without causing any interruption in their services in order to meet the new emission requirements.

Main challenge for DH companies in meeting the emission reduction goals lies in shifting from fossil fuels to renewables as an energy source in heating production. A feasibility study has been prepared in 2019 by Vattenfall and Berlin Senate Department for Environment, Transport and Climate Protection to draw the road map. According to this study, energy mix for coal power stations in Reuter West and Moabit will be replaced and coal power stations will be shut down by 2030 (Ritzau et al., 2019). Right now, there are many low carbon supply options in the market that can replace coal such as power-to-heat, hybrid CHP or biomass.

Due to different historical backgrounds, both halves of the city pose different challenges in terms of DH networks. Natural gas has the largest part in the energy mix for Berlin DH systems together in the east and the west (Figure-2). On the other hand, Figure-3 shows that coal powered CHP systems are the main heat source for DH network in the west Berlin system.

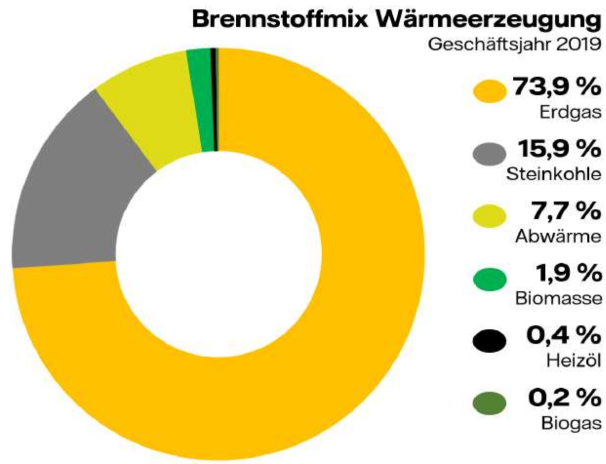

Figure 2-Berlin Vattenfall DH system fuel mix in2019 (Vattenfall, 2020a)

Technologies that can replace coal-powered CHPs vary and it is important whether they are suitable for Berlin. If phasing out of coal until 2030 is the first step, being climate neutral by 2050 can be considered as the second one. However, volatile characteristics of renewables require inclusion of natural gas into the system at the moment.

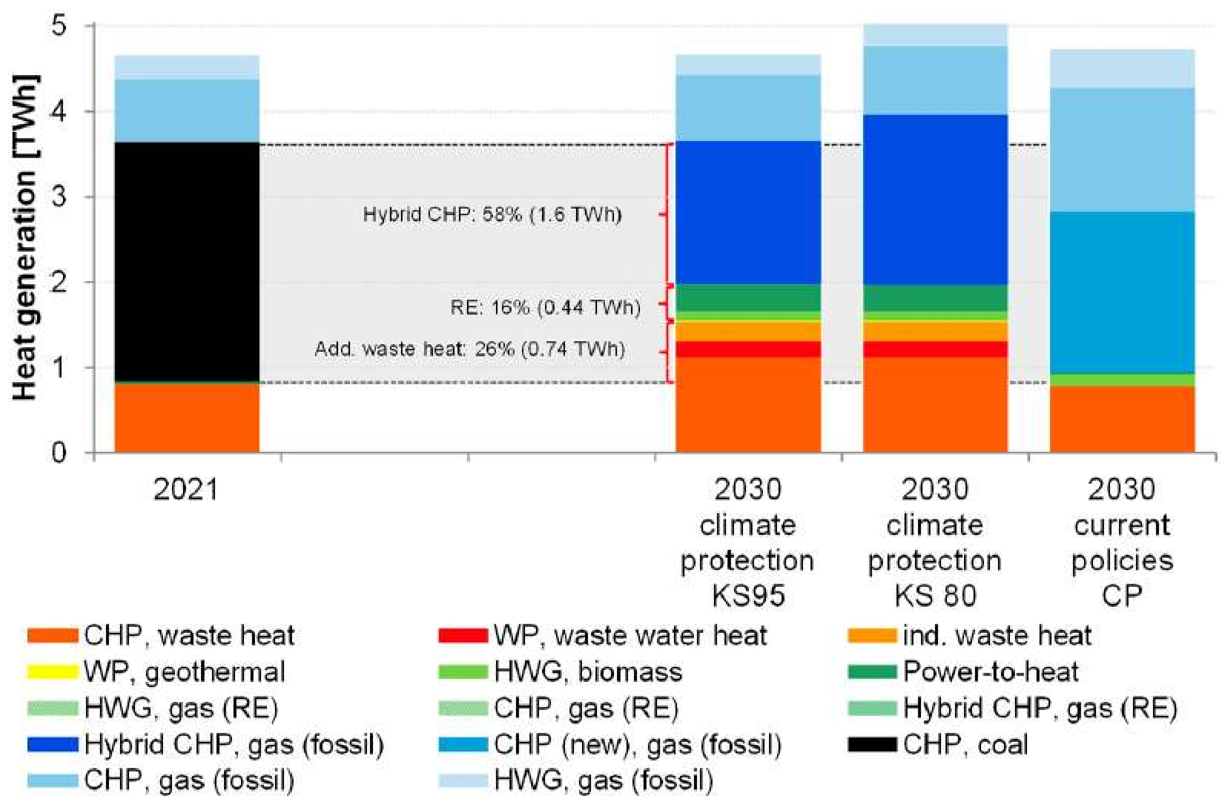

Figure 3-DH heat supply scenarios for 2030 in West Berlin (Gonzalez-Salazar et al., 2020)

For low carbon DH systems, functioning of the electricity market is important as CHP units produce electricity and heat. Another challenge is the changes in the building stock in the city, whether the city is expanding, or the heat demand of the building stock is changing. Along with the required change of the energy mix, the problem is multi-faceted.

Technical Solutions for District Heating Challenges in Berlin

Reducing the dependency on fossil fuels is a crucial step for a carbon neutral future and this requires changes in the energy mix. Alternatives for Berlin vary: biomass, sewage and municipal waste heat recovery, excess heat from industry and commerce, geothermal, and hybrid CHP (Gonzalez-Salazar et al., 2020).

Biomass potential of Berlin is variable on the radius that can provide biomass fuel such as forestry residues and the availability of the DH infrastructure which can handle solid fuel with adequate storage space (Gonzalez-Salazar et al., 2020). As the radius increases, biomass potential increases as well; however, utilization of these resources would require cooperation with other states (Vattenfall, 2020b). Within a 100 km radius of the city, there is a biomass potential to feed a boiler with a production capacity of 0.71TWh/pa if it is working 90% of the time.

Municipal solid waste from 2 million households in Berlin is already incinerated in Ruhleben plant since 1967 and the steam is delivered to a CHP unit operator (Gonzalez-Salazar et al., 2020). It is possible to provide more heating from waste incineration through new CHP units and through the utilization of low heat from the flue gas. Another addition can be using a heat pump for the low temperature heat from the sewage treatment plant. These changes would contribute to DH heating with production capacity of 1.3 TWh/pa.

Another option is using excess heat from industries and commercial companies. The temperature level of excess heat and distance of these companies from the DH network are determining factors in the feasibility (Gonzalez-Salazar et al., 2020). Theoretically, 0.28 TWh/pa production is possible in West Berlin area.

Berlin has a geothermal heat potential in the depths of 2000m (Gonzalez-Salazar et al., 2020). To ensure the suitability of production areas, more extensive studies are needed. First studies confirm a thermal output of 8 MW with the integration of a heat pump and an aquifer.

Due to seasonal characteristics of renewables, a hybrid CHP system which uses both gas and electricity stands out as one of the feasible options (Gonzalez-Salazar et al., 2020). Power-to-heat can be used to generate hot water from electricity and that way excess electricity from wind and solar can be utilized. If compliant policies are followed, power-to-heat is expected to have a production of of 1.7TWh/pa. It is important that the CHP unit is flexible for uses of natural gas, synthetic natural gas, or hydrogen. CHP plants can be operated when renewables are low on supply and when the renewables supply is adequate, CHP plants can be stopped. This type of CHP plant has a capacity between 503MW and 644MW thermal output.

Overall, there is a possibility of 4.1TWh/pa energy production from low carbon sources. The potential capacities will be different for the east part of the city, or with different policies, however this modelling still provides an idea about the degree and the technologies of the required change in the DH system.

The challenge of being carbon neutral by 2050 can be planned in steps. By 2030, energy mix for DH systems will be partially substituted by low carbon sources and natural gas will still be holding an important place. As energy market transforms, the renewables share would be increasing.

Achieving Through the Foreseen Challenges of District Heating Systems

DH network is an important part of urban infrastructure in Berlin and it is responsible from 15% of final energy consumption in the city (Berlin SenUVK, 2015). Due to utilization of CHP units, it is also closely connected to the electricity sector. The largest company in Berlin DH market, Vattenfall, can be considered as a monopoly since it owns 90% of the DH network in the city. DH is provided with a centralized system, with various plants supplying hot water around the city. The distance covered between the user and the heating plant is an important factor in DH network efficiency and profitability. Due to its high fixed costs and relatively low marginal costs, it is a "winner-takes-it-all" system, and competition is not between various existing system providers but rather about who will get the chance to own the network.

Like many other cities in Germany, Berlin has climate goals for 2030 and 2050 which is leading to important changes in the energy mix. Introduction of renewables to the grid create a more volatile energy supply chain which requires the DH network to be more flexible (Rubczyński, 2018). Another sector, electricity, which is closely related to DH sector, is widely affected by the volatility of renewables. For variable flows of the energy grid intelligent networks are needed to be implemented which requires a technological know-how. Adding to that, sector coupling is also expanding the use of electricity in various sectors.

Interconnectedness of various sectors with various infrastructures creates the ecology of technical infrastructure systems. For DH network in Berlin, there are many future scenarios which are linked to other systems technically or legislatively. Biomass requires cooperation with nearby federal states for resource collection, excess heat requires being connected to industries, and CHP plants are an important part of electricity sector and power-to-heat systems mean shifting demand to power sector. Moreover, all potential energy production options pose important challenges to the urban planning of the city in terms of space used and disturbance given to residents.

The predominantly used fossil fuels such as brown coal, hard coal and natural gas are to be replaced with renewables whose technological know-how is still not as developed as fossil fuels'. It is a challenge for the DH sector to find ways of functioning without interruptions and also in harmony with other sectors. Forecasting and modelling are required tools for a harmonious transition. These tools are design frameworks which can compute different scenarios. "Design" can be described as a way of seeing and acknowledging the relations between parties. It can be about relations between environment and man, user and game or infrastructures and city. DH network physically link users which are in the vicinity of each other. Being a complex design problem, ecology of urban infrastructures in Berlin is inclusive of residents, companies, other states, government agents, institutions. Eventually through its tools it will be defining how they will achieve to work harmoniously. It is within possibility that problems will be faced during the energy transition period however it is also very likely that the knowledge base which is already in the system will be compensating the negativities.

Historically, it has been a challenge to provide hot water to residents of Berlin. Two world wars followed by the division of the city, increasing population and climate change goals of today are some of the considerable challenges. Due to these, DH system had to be renewed, recovered and restructured multiple times. Today, the network is still expanding by 25.000 users per year (Vattenfall, 2020a), which shows that demand from the city is still growing. As urban infrastructure systems merge into each other more, the framework of ecology is more helpful to build realistic models. With sector coupling and increasing the share of renewables, the energy mix and supply chains are in constant change. With the “ecology” framework; through concepts like nature of monopolies, network effects, or reliance on digital technologies, DH networks can be more accurately modelled and managed.

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