BIG SOLAR GRAZ: SOLAR DISTRICT HEATING IN GRAZ – 500,000 M² FOR 20% SOLAR FRACTION

Patrick Reiter, Hannes Poier and Christian Holter
S.O.L.I.D. Gesellschaft für Solarinstallation und Design mbH, Puchstrasse 85, Graz, 8020, Austria,
+43 (0) 316-29284054, +43 (0) 316-29284028, p.reiter@solid.at

Abstract – Current heat generation for district heating (DH) in Graz, Austria is primarily from waste heat of fossil-fired combined heat and power (CHP) plants. Due to low prices on the European electricity market, the operation of CHP plants is not economically sound anymore and may lead to problems for cities, that are highly dependent on the heat of such plants. Thus, the operator of the CHP plants in Graz recently announced their closure in 2020. Almost 80% of the overall heat production has to be replaced.
The research focus of this paper is to analyze the technical and economic potential of integrating a centralized large-scale solar thermal system including seasonal pit storage and heat pumps for DH. Therefore, the purpose of the research is to determine the techno-economic optimum size of such a solar system, that can be integrated into the district heating system. The study includes the design of a technical concept using dynamic simulation, an investigation of appropriate land for collectors and the storage and an economic cost evaluation of its realization.

Keywords: Solar district heating; large-scale solar thermal system; seasonal pit storage;

1. DISTRICT HEATING IN GRAZ

Graz is located in the southeast of Austria and is capital of the federal state Styria. It is the second largest city in Austria with an estimated population of 257,526 (Stadt Graz, 2012). District heating (DH) in Graz was inaugurated in 1963 with the initial operation of a DH power station (steam generator with connected turbines) (Bloder, 2010). Through a steady extension of the grid utility the share of heat supply by DH steadily increased over the years, despite the fact of increasing energy efficiency by building refurbishment (Bloder, 2010).

The energy used for heating and hot water in residential and service buildings of Graz was approximately 2,100 gigawatt hours (GWh) in 2009 and is currently estimated to 2,400 GWh per year. DH covers with approximately 935 GWh per year (in 2013) 39 percent of the overall heat demand in Graz and 1,100 GWh per year including the southern communities around Graz (Grazer Energieagentur, 2014a). Until 2030 it is planned to further extend the DH net up to a share of 56% of the overall heat demand.

Figure 1 shows the stage of extension of the DH grid in Graz. Deep red areas mark the current DH net, while the slight red areas show the planned extensions until 2020. The orange areas show the gas supply network of the city of Graz. The DH system in Graz is a pressurized water system with an operating temperature up to 120°C in winter and around 75°C in summer, and has return flow temperatures of approximately 60°C (Bucar, 2006). The system is operating all seasons throughout the year and the heat is emerging from various power plants, but primarily from so-called combined heat and power (CHP) plants. DH pipes in Graz are between 25 mm and 600 mm diameter. Within these diameters, different types of main transport, side and house service connection pipes are installed (Bucar, 2006).

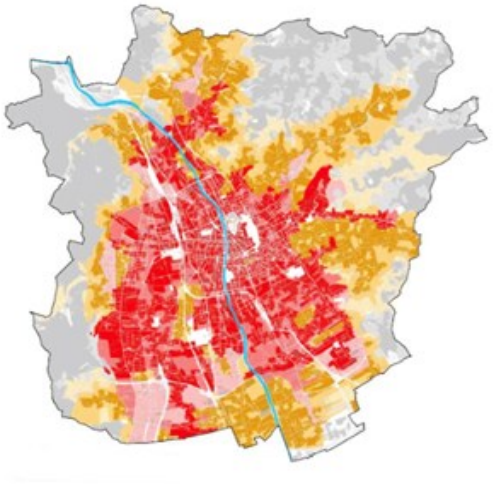

Figure 1: Overview of DH connections in Graz (red).

Table 1 illustrates data to the current DH net of Graz and its southern communities called GU Süd.

Table 1: Data of the current DH in Graz and the southern communities of Graz.

	City Graz	GU Süd
Total heat amount per year (incl. distribution losses)	~ 1050 GWh [2013]	165 GWh [2013]
Share winter term	~ 84%	~ 90%
Peak load (February 2012, outside air temperature -13.4°C)	425 MW	70 MW
Flow temperature raised up to max.:	120°C	110°C (Subnets 90°C)
Route length	~ 370 km	~ 201 km
Transmission stations	~ 5,700	~ 3,000

The most important heating sources for the DH network in Graz are the DH plants at Puchstrasse, and the CHPs in Mellach and Werndorf-Neudorf, which are located 15 to 20 km south of Graz. These CHP plants are with more than 85 percent of the overall produced heat the biggest supplier in the DH net in Graz and are operated by the Austrian electricity provider Verbund AG. The DH power plant at Puchstrasse is fired with natural gas and has a maximum thermal capacity of 280 MW (Grazer Energieagentur, 2014b). The CHP plant in Werndorf-Neudorf is mainly fired with oil and has a maximum thermal output of 200 MW (Grazer Energieagentur, 2014b). In Mellach there are two CHP plants. One DH power station that is fired with coal with a maximum thermal output of 230 MW. The second one, established in 2012, is a modern gas fired CHP plant with a maximum thermal output of 400 MW (Grazer Energieagentur, 2014b).

However, due to low energy prices the gas-fired CHP plant was put out of operation in 2014. In a press release of 14th of May, 2014 Verbund AG announced that due to the massive drop on the European electricity market they were forced to temporarily and even fully shut down some of their power plants in Austria and France (Verbund, 2014). Graz was highly affected by this press release since the two largest power plants for DH had to be closed. Due to a court's interim conjunction Verbund AG was not allowed to fully shut down the gas-fired CHP in Mellach in order to work as a standby unit for the coal-fired DH power station. The contractually agreed thermal output is limited to 230 MW (Grazer Energieagentur, 2014d). The coal-fired CHP plant in Mellach is still operating but will be shut down in 2020 due to the fact that the heating supply contract between Verbund AG and the regional energy provider Energie Steiermark will end in 2020. Moreover, the plant is already operating since 1986 and is in the end phase of its operating life (Grazer Energieagentur, 2014b). The trend in the European electricity market has changed dramatically in the last years, electricity prices are sinking rapidly and modern high efficient gas-fired CHP plants, such as the new established plant in Mellach, are not that economically sound anymore (Grazer Energieagentur, 2014d). Through the closure of the CHP plants in and nearby Graz, no waste heat from electricity generation is available anymore and subsequently has a significant impact on DH in Graz.

Figure 2 illustrates the DH generation for Graz and the southern communities of Graz by power plants. Furthermore, Table 2 shows the used fuel and detailed numbers for thermal capacity, the yearly heat provided and share of each plant.

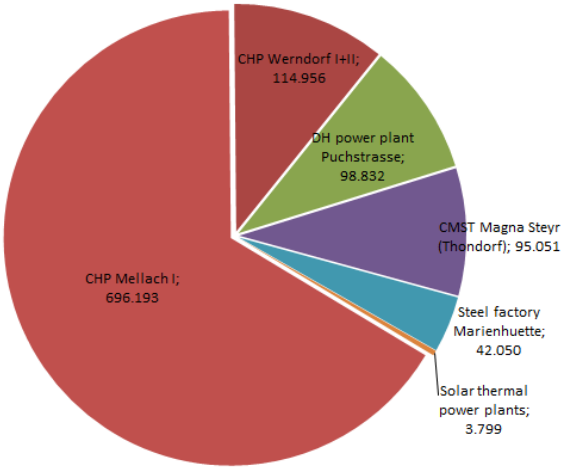

Figure 2: Heat generation for DH in Graz in MWh/a.

Table 2: DH generation for Graz and the southern communities around Graz listed by power plant.

DH generation	Used fuel	Thermal capacity [MW]	Yearly heat supply [MWh/a]	Share [%]
CHP Mellach I	Coal	230	696,193[2]	66.25
CHP Mellach II	Natural gas	400	0[3]	0
CHP Werndorf I+II	Oil, Natural gas	200	114,956	10.94
DH power plant Puchstrasse	Natural gas	280	98,832[2]	9.40
CMST Magna Steyr (Thondorf)	Industrial waste heat	35	95,051[2]	9.04
Steel factory Marienhuette	Industrial waste heat	15	42,050[2]	4.00
Solar thermal plants (Liebenau, Andritz, AEVG)	Solar power	7.2[1]	3,799[4]	0.36
Overall		**1,167.2**	**1,050,881**	**100**

[1]theoretical maximum output; [2]average between 2006 – 2011; [3]CHP Mellach II only operated during a test phase; [4]solar output 2012.

In 2014 the Graz city senate constituted a project team to find various options for providing heat for DH in Graz and its surrounding communities for 2020/30 (Grazer Energieagentur, 2014d). The city senate enacted main objectives, which have to be taken in consideration. These main objectives are: (1) no deterioration of the primary energy factor of DH-generation; (2) no deterioration of specific greenhouse gas emissions (g/kWh); (3) consideration of the current emissions in Graz; (4) no increase of the costs, compared to other types of heating; and (5) security of supply and quality (Grazer Energieagentur, 2014c). Different working groups were established and a variety of experts and stakeholders were invited in order to find possible

solutions for the future heat supply of the DH net in Graz. In particular 9 workshops with more than 200 experts participating were held in order to find short and long term solutions for the future provision of heat for the DH net in Graz (Grazer Energieagentur, 2014d). According to the working group, an estimated additional thermal output of 400 MW is needed in 2020 due to the closure of the CHP plants in Mellach and Werndorf. The estimated maximum thermal demand for Graz and its surrounding communities will be at approximately 599 MW in 2020 and at 658 MW in 2030 (Grazer Energieagentur, 2014d). This will be realized on the one hand by the construction of additional gas-fired boiler plants at the DH power plant in Puchstrasse with an estimated thermal output of 200 MW, by decoupling industrial waste heat from nearby industries and several other minor enhancements in the actual infrastructure. On the other hand, it will be realized by increasing energy efficiency by building refurbishment, by optimizing the DH grid and by developing clear concepts for future large-scale low-carbon power plants in geothermal heating, biomass and solar thermal heating. Especially the realization of a large-scale solar thermal power plant in combination with seasonal storages and heat pumps offers great potential in terms of provision and security of supply of heat and hot water for the future DH net in Graz. Therefore, the local energy provider agreed to carry out a feasibility of such a large-scale solar thermal power plant in order to analyze its potential in detail.

2. BIG SOLAR GRAZ: TECHNICAL AND ECONOMIC FEASIBILITY STUDY

2.1 Overview

In June 2015 the company *S.O.L.I.D.* has been assigned to develop in cooperation with the regional energy provider *Energie Steiermark* a technical and economic feasibility study for integrating a large-scale solar thermal system into the DH network of Graz. It is being realized with the technical assistance of *PlanEnergi*, a Danish consultant company, which has extensive experience in modelling systems for dynamic simulations of large solar thermal systems and seasonal storages, and the local consultancy *Energy Agency Graz*. The study was supported and partly funded by the *Austrian Research Promotion Agency*, the *Climate and Energy Fund*, the *Province of Styria* and the *City of Graz*.

Since a variety of different topics have to be investigated and several collaborative partners were involved, the study has been divided in different specific work packages (WPs) in order to get a full and detailed analysis for a successful realization of such a concept.

The work packages are the following:

WP 1: Collection of basic data & analyzation of boundary conditions
WP 2: Dynamic simulation of energy balance
WP 3: Economic analysis
WP 4: Financing and Business Case
WP 5: Assessment of available land
WP 6: Legal framework
WP 7: Storage

2.2 Concept

The BIG Solar Graz concept foresees a maximum solar fraction with a competitive heat price compared to heat from gas boilers for the DH network of Graz. Different sizes of the collector field, the pit storage and the absorption heat pumps (AHPs) were simulated between a certain range, to find a system optimum for dimensioning each component. AHPs play a key role in this concept, leading to an essential yield improvement of the specific net solar heat production.

For having a first estimation of the potential for the concept the load profile of the DH net was divided in two shares. A low temperature share provided either from solar and the storage directly or via AHPs and a high temperature share, which needs to be provided from high temperature sources such as gas or biomass boilers. Figure 3 illustrates these two shares. Orange is the low temperature share which could be covered by the Big Solar system and blue the share for high temperature sources. By taking this calculation into account the Big Solar share may be arround 55% of DH in Graz within the current boundary conditions. Moreover, by taking into account that only one part of the energy is supplied by solar and the other part is supplied by the driving energy for the thermal heat pump which might be gas, but also could be biomass the pure solar output would be 33%. Therefore detailed investigations of the concept were performed up to a solar fraction of 30%.

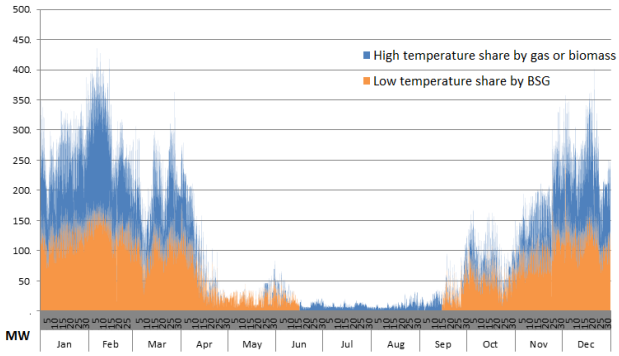

Figure 3: Load profile of DH in Graz divided by temperature needs.

An extensive part of the study was to simulate the feed-in from the Big solar system into the DH net. For a detailed data synchronization, representative heat load profiles have to be taken into account. Therefore, actual data of 2014 is used as a basis. Multiple TRNSYS simulations were being performed up to a maximum solar fraction of 30% in order to evaluate the optimum in both, its technical and economic feasibility. Therefore, a number of simulations for collector field sizes between

20,000 m² up to 1 Million m², pit storage sizes between 100,000 m³ up to 2 Million m³ and 3 different sizes of AHPs (0, 50 and 100 MW heat output) were made.

3. RESULTS AND FUTURE OUTLOOK

The multiple TRNSYS simulations with the different parameter variations resulted in a techno-economic optimum of 450,000 m² collector field area, a seasonal heat storage capacity of 1,800,000 m³ and AHPs with a total heat capacity of 100 MW. Within the analysis technical limitations such as the maximum capacity of the DH transport line, current heat and temperature loads, but also future heat loads by the consideration of future waste heat potentials from industries, were taken into account. Furthermore, a comprehensive cost evaluation was performed by dynamic capital budgeting.

Figure 4 (See Appendix) illustrates the simulated heat production for the DH net in Graz with the techno-economic optimum BIG Solar Graz concept. Heat production is divided by months and shows the different sources which are used to meet the overall heating demand.

Simulations show that the BIG Solar concept is technical and economic feasible. The economic analysis shows that a heat price is comparable to other heating sources for DH in Graz. Although such a system has high upfront investment costs the payback-time is moderate and economically reasonable, even with neglecting the additional environmental benefit. Moreover, it has to be said that on both, a technical and an economic point of view, the project is quiet flexible. This means that giving the boundary conditions in Graz including land availability, the size of the solar system can vary between 150,000 and 650,000 m² respecting the adaptation of sizes of the pit storage and the AHPs by feasible and economic sound price ranges. However, some issues have to be still investigated in more detail, which were not addressed in this feasibility study and are part of a later planning phase.

REFERENCES

Bloder, A., (2010). Klimaschutz- und Energiebericht Stadt Graz, Master thesis.

Bucar, G., (2006). Dezentrale erneuerbare Energie für bestehende Fernwärmenetze, Project report within the programme „Energiesystem der Zukunft“.

Grazer Energieagentur, (2014a). Ausgangsdaten und Rahmenbedingungen Wärmeversorgung Graz 2020 / 2030.

Grazer Energieagentur, (2014b). Green Paper Wärmeversorgung Graz 2020 / 2030.

Grazer Energieagentur, (2014c). Wärmeversorgung Graz 2020 / 2030 Ergebnisse der Fachworkshops und der Diskussionsbeiträge der Arbeitsgruppe.

Grazer Energieagentur, (2014d). Wärmeversorgung Graz 2020/2030 Optionen für die Wärmebereitstellung fernwärmeversorgter Objekte im Großraum Graz.

Stadt Graz, (2012). Bevölkerungsprognose für die Landeshauptstadt Graz.

Verbund, (2014). VERBUND: Decision on Thermal Power Plant Portfolio. Available at: http://www.verbund.com/cc/en/news-media/news/2014/05/14/entscheidung-thermisches-kraftwerksportfolio.

APPENDIX

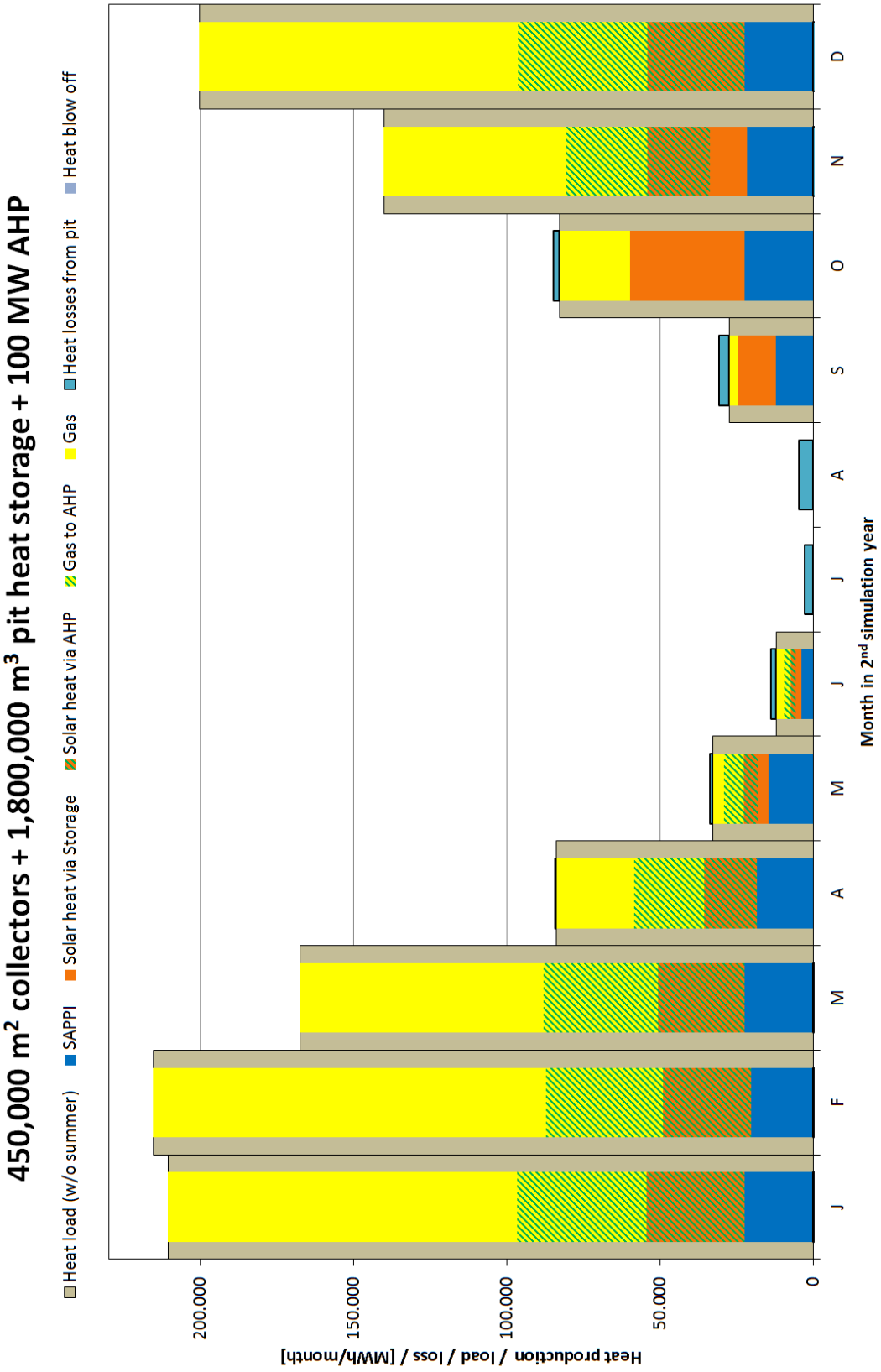

Figure 4: Monthly heat production over one year with techno-economic optimum BIG Solar concept.