OPERATIONAL ANALYSIS AND DETAILED MONITORING RESULTS OF MEASUREMENTS TAKEN FROM LARGE-SCALE SOLAR THERMAL PLANTS INTEGRATED INTO DISTRICT HEATING

S. Knabl, C. Fink, W. Wagner, R. Stelzer
AEE – Institute for Sustainable Technologies
Feldgasse 19, 8200 Gleisdorf, Austria
Tel.:+43 (0) 3112 - 5886 – 229
E-Mail: s.knabl@aee.at
Web: www.aee-intec.at

B. Windholz, F. Helminger
AIT – Austrian Institute of Technology
Giefinggasse 2, 1210 Vienna
Tel.:+43(0) 50550-6385
E-Mail: bernd.windholz@ait.ac.at
Web: www.ait.ac.at

Abstract – In 2009 the Austrian Klima- und Energiefonds started a funding programme for the development and further market penetration of large-scale solar thermal systems for industrial and commercial applications. Funding could be obtained for innovative system concepts of between 100 and 2,000 m² covering solar process heat applications, solar district heating plants, solar heating and cooling applications as well as solar combi-systems with high solar fractions of above 20 %. In order to ensure high quality and functionality applicants had to take advantage of a scientific consultancy beforehand. Later on the most interesting projects in terms of innovation and replicability were chosen for a 12 months solar thermal system monitoring, analysis and optimization by a scientific partner. Between September 2009 and September 2015 261 application forms were successfully handed in summing up to a total collector area of around 94.000 m². Of these, 84 projects were equipped with additional sensors for monitoring. By July 2016 monitoring and analysis was finished for 33 large-scale solar thermal systems including 14 solar district heating plants and monitoring is currently ongoing for three more SDH plants respectively for 13 more plants the start of monitoring phase is in preparation. In this paper detailed monitoring results covering both the characteristics of the solar circuit as well as the entire energy balance of the selected systems including auxiliary energy flows, heat losses and parasitic energy consumption are analysed.

1. INTRODUCTION

For six years the Austrian Climate and Energy Fund (KLIEN) has been sponsoring a subsidy program specifically for large-scale solar thermal plants for industrial applications, including scientific monitoring. In total, 261 projects were submitted covering 94,000 m² of gross collector area and due to high demand the Austrian Klima- und Energiefonds (KLIEN) continued the funding programme in 2016 as well. In order to gain knowledge essential for the further development of the solar thermal technology, the 84 most innovative and promising were selected for scientific monitoring which includes analysing monitoring data over one operational year.

2. THE FUNDING PROGRAMM

The programme managed by the Austrian Klima- und Energiefonds (KLIEN) is aimed at the implementation of solar thermal energy in the industrial and commercial sector according to four categories (plus a fifth category for "new system intelligence" since 2013):

- Solar process heat applications
- Solar district heating (SDH)
- High solar fraction (> 20 %) in buildings for industry and services
- Solar cooling applications
- New system intelligence (hybrid systems such as PVT, new collector and storage developments, etc.) bridging the gap between R&D and market entry

Funding is provided for a maximum of 40% of the environmentally relevant additional costs (environmentally relevant investment costs minus the costs of a reference heating system based on oil) with an additional 5 % for projects implemented by SMEs. The total maximum funding rate therefore is 45 % of the environmentally relevant additional costs. The funding is intended for covering the entire material and labour costs related to the solar thermal circuit including storage for systems with a gross collector area of at least 100 m² and a maximum of 2,000 m² (respectively 50 m² to 200m² in category five "New system intelligence"). Caps are implemented specifically for each category in order to limit the maximum funding per plant. In summary 261 projects with a total gross collector area of 94.000 m² has

been submitted to the programme. Image 1 provides an overview on the projects submitted for funding so far according to category and size.

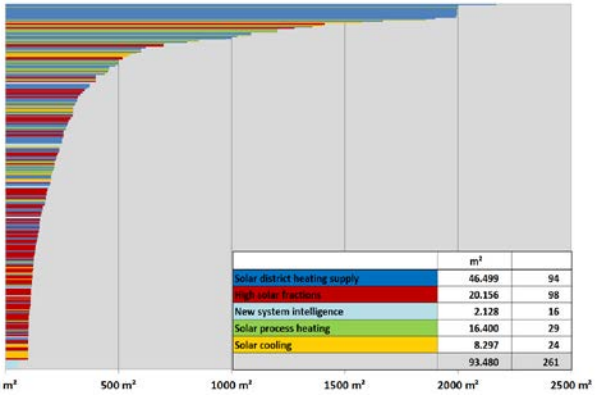

Image 1: Presentation of the total of submitted projects arranged by gross collector area and colour-coded according to the category of application.

From this image it becomes clear that around 20% of the plants have gross collector areas of larger than 500 m². The categories “solar district heating” and “high solar fraction (> 20 %) in buildings for industry and services” make up most of the projects (around 100 projects each).

3. SCIENTIFIC MONITORING PROGRAMME OF AUSTRIAN SDH PLANTS

In order to maximize the benefit and effectiveness of the previously described funding plan, the KLIEN assigned a scientific monitoring programme headed by AEE INTEC (in cooperation with AIT). The main tasks of this monitoring are:

- Technical consulting preparatory to submission to the funding programme
- Supervision for projects with highly innovative approaches in during the phase of detailed planning and in the course of the implementation of the plant
- Definition of the monitoring concept (input and output of the energy balance) for projects with a highly innovative approach
- Implementation of the metrological monitoring of the heating system for at least one year of operation for selected projects with a highly innovative approach
- Plant analysis and benchmarking
- Deduction of possibilities for technical improvements and identification of need for further research
- Consulting services to the funding agency (KLIEN) for adjustments and further development of the programme

Up to now 84 projects have been selected for the one year monitoring phase by a panel of experts and by end of July 2016 33 of these projects have already completed the monitoring phase including 14 solar district heating plants. For three SDH plants it is currently ongoing and for 13 more plants the start of monitoring phase is imminent.

Due to the different heat distribution networks characteristics a differentiation into three sub-categories (biomass district heating, urban heating networks, microgrid integration) was performed. Image 2 provides an overview of the Austrian SDH projects divided into these three different categories. The majority of the monitored systems are typical biomass district heating integrations, such as the project "Nahwärme Eibiswald" with a 2450 m² gross collector area. But also smaller projects such as the project "Nahwärme Düringer" with 100 m² gross collector can be assigned to this sub-category.

SDH projects which feed directly resp. into the sub network of an urban heating network represent the second sub-category. To date one project ("Salzburg Lehen") in this sub-category completed the one year monitoring phase and one project is currently ongoing ("Heating Plant II - Graz"). For three more projects the start of monitoring phase is imminent. The average gross collector area in this sub-category with more than 1000 m² is the highest among the three sub-categories.

The third categories are solar thermal microgrid integrations. Examples include decentralized heat supply systems of multifamily houses or larger apartment complexes ("Lexengasse", "Waldmühle Rodaun"). Furthermore the integration of solar thermal heat into the heat supply systems of hospitals ("Elisabethinen Hospital", "UKH Graz"), shopping centers or production facilities ("SFL Technologies") can be assigned to this sub-category.

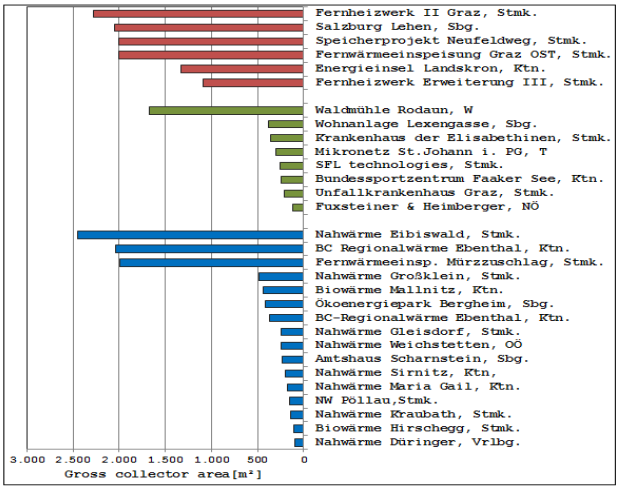

Image 2: Presentation of the three sub-categories of Austrian SDH projects (biomass district heating systems - blue, urban heating networks - red, microgrid integration - green)

4. DESCRIPTION OF REPRESENTATIVE AUSTRIAN SDH PILOT PLANTS

This chapter presents the experience gained from four solar district heating applications constructed and monitored in the framework of the Austrian funding programme. Moreover the most important technical benchmark figures are shown separately for each plant.

4.1 Solar assisted low-temperature district heating grid Salzburg-Lehen (2.048 m² gross collector area)

In 2011 an entirely new residential area has been constructed in the district of „Lehen" in the city of Salzburg on the former operation site of Stadtwerke Salzburg, consisting of two- to eight-storey apartment buildings with a total of 300 housing units plus a students' residence, a kindergarten, offices and shops (see image 3 for an impression of the area). The total housing and commercial area amounts to 38,000 m². The heat supply is provided by a newly constructed low-temperature heat network (65/35°C). Roughly one third of the energy is covered by solar thermal energy from 2,048 m² of gross collector area implemented in combination with an energy storage of 200 m³.

Image 3: View on part of the 2,048 m² gross collector area distributed over 13 buildings. Picture source: AEE INTEC

The collector area is composed of 13 fields which have been mounted on the flat roofs of the buildings and which feed into the central energy storage. Furthermore, a heat pump with a peak capacity of 160 kW has been installed and connected to the energy storage. This leads to lower temperatures in the lower part of the energy storage and therefore allows for higher solar energy yields and higher energy densities to be achieved at a given volume. The Salzburg community heating provides auxiliary energy whenever necessary and also feeds into the central energy storage. From here the heat is distributed to the different consumers via a two-pipe network (decentralized hydraulic units in the multi-storey buildings). This way not only the newly constructed objects but also some refurbished apartment buildings with a total of 160 housing units are supplied.

The monitoring phase of one year for this project was completed in July 2014. The analysis showed very satisfying system performance and functionality. The specific solar yield for this plant was 533 kWh/(m²aperturea) covering more than 23 % of the thermal energy demand.

4.2 Solar assisted biomass heating network Eibiswald, Styria (2,450 m² gross collector area)

Since 1994 a biomass district heating network has been supplying energy to various buildings in Eibiswald. In 1997 solar thermal energy has been integrated into the network through the installation of 1,250 m² of collectors and a heat storage of 105 m³. The solar thermal plant was initially designed to provide 90 % of the energy demand in summer (July and August). Since that time the heat demand has increased considerably due to the integration of new consumers to the grid. The heat demand forecast for one year currently is 7.5 GWh. The solar fraction has decreased correspondingly as the solar yield remained at the same level. Against this background the district heating company decided to increase the solar capacity and a new plant with 1,200 m² was installed on the roof of a new storage room for wood chips ion 2013 (as can be seen on the right in image 4). Furthermore, a storage tank with a volume of 68.5 m³ had to be integrated additionally to the already existing 105 m³.

The monitoring phase was completed in April 2014. The functionality of the plant was proved to be unproblematic. It can be pointed out that both the new and the old plant have been monitored and analysed and that the measured solar yield of 430 kWh/(m²aperture·a) is considerably higher than the simulated value of 411 kWh/(m²aperturea). The solar fraction in July and August was 78 and 92 % respectively. The cumulative solar fraction for the whole year was around 12 %.

Image 4: View on the collectors situated on the roofs of the two storage buildings for the wood chips (on the right the new installation with 1,200 m², on the left the old collector field with 1,250 m² gross collector area). Picture source: AEE INTEC

4.3. 438 m² of gross collector area support the energy supply of the community district heating network Mallnitz

The biomass energy plant in Mallnitz operates a district heating network with roughly 4 MW of connected load, supplying 125 buildings (commercial buildings, primary school, single-family houses, apartment buildings, swimming pool, etc.). The energy is provided by a 1,700 kW biomass boiler, a solar thermal system with a gross collector area of 438 m² as well as a biomass CPH plant with a maximum thermal output of 550 kW.

Particularly interesting about this project is the combined use of the solar thermal plant and the biomass CPH. During the summer the load is supplied primarily by the biomass CPH and the solar thermal plant in combination with an 80 m³ storage tank.

The monitoring phase for the solar thermal on the roof of the boiler house was completed September 2015. In general the operation of the plant was stable. The solar yield for the monitoring phase is 385 kWh/(m²aperturea) and the solar fraction is 1.5 %. The combined operation of the solar thermal system with the biomass CHP can be regarded as good. The target set by the operator target, largely to ensure the power supply by the biomass CHP and solar thermal plant in the summer has been achieved.

Image 5: View on the 438 m² of collectors on the roof of the storage building for wood chips. Picture source: Hoval GmbH.

4.4. Integration of 255 m² gross collector area in a low-temperature micro-network of an industry site

In 2014 SFL technologies GmbH expanded their company premises in Stallhofen near Voitsberg. In order to cover the heat supply of the whole site, a micro-network assisted by solar thermal energy was implemented. For this purpose a collector area of 255 m² was installed. A gas boiler with 450 kW and four heat pumps with a total capacity of 360 kW serve as the primary heat source.

Image 6: View on the 255 m² collector area installed on the roofs of the two production buildings. Picture source: H. Traussnigg GmbH.

The solar thermal system is used for helping to provide the energy for heating and hot water throughout the year as well as for regenerating the deep geothermal heat exchanger during summer. The geothermal field consists of 42 probes with a depth of 147 m each. Furthermore, three storage tanks with a combined volume of 15.5 m³ were installed for storing the solar heat. This project is particularly interesting because of the operating behaviour of the solar system in a multivalent heat supply system.

The monitoring phase required by the funding programme started in September 2015. The solar yield simulated for the submission to the programme is 366 kWh/(m²aperturea) and the solar fraction is aimed to be 4.5 %. The data measured up to now coincides with these values and therefore indicates that the target can be achieved.

5 BENCHMARKS AND COMPARISON TO SIMULATION VALUES

The four projects described above are subject to the scientific monitoring programme. For this purpose all heat inputs as well as outputs are registered. The main benchmarks of the plants have been defined as: the specific solar yield, thermal energy supply and resulting here from the solar fraction (definition: solar input in relation to the sum of solar input and conventionally generated heat). The following image 7 shows these benchmarks for the four exemplary plants compared to the respective values predicted by simulation.

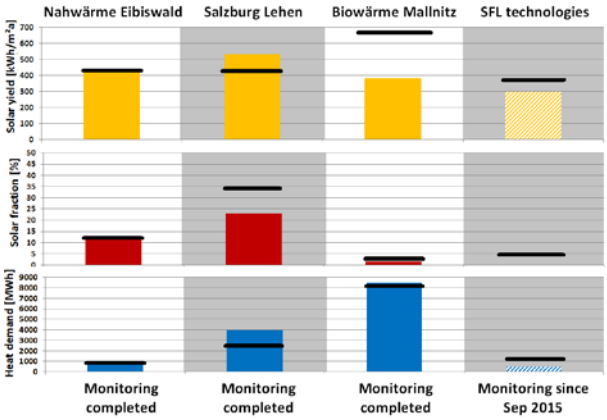

Image 7: Comparison of the measured specific solar yield (orange), solar fraction (red) and heat demand (blue)of four solar thermal plants and compared to the simulation values (black lines). The plant (SFL technologies) which have not yet completed the monitoring phase are marked by shaded bars.

Three of the plants have already completed the monitoring phase while for the other one (SFL technologies) it is still ongoing (shaded bars). The specific solar yield for these plants range from 385 to 533 kWh/(m²aperturea). Two of the plants managed to outperform the simulation values ("Nahwärme Eibiswald", "Salzburg Lehen") while one plant ("Biowärme Mallnitz") did not reach their targets. The results and operating experience of the remaining plant

"SFL technologies" which is still undergoing the monitoring phase suggest that the simulated benchmarks can be reached or possibly exceeded.

In addition to compiling the energy balance and calculating the benchmarks, the heat supply systems have been analysed in detail (including all hydraulic circuits as far as possible) with regard to functionality and temperature levels.

6 OUTLOOK

The Austrian funding programme for large-scale solar thermal plants has been well received on the market in the past years. The programme is therefore continued in 2016. The scientific monitoring for the plants has proved to be an essential part of the initiative and provides valuable feedback for the adaptation of the programme as well as for the further development of the technology.

7 REFERENCES

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