Proc. ISES Solar World Congress, Johannesburg (SA), 11.-14.10.09

# SOLAR PROCESS HEAT IN BREWERIES - POTENTIAL AND BARRIERS OF A NEW APPLICATION AREA

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## Abstract

Only a negligible number of solar heating systems heat which have been realised so far provide process heat even though a large number of processes in different industrial sectors consume large amounts of thermal energy at temperatures from 80 to 250 °C. This is mainly caused by complex system integration, missing procedural knowledge and economical restrictions. A case study of the Hütt brewery in Kassel (Germany), a typical small to mid sized brewery, demonstrates the general approach for the integration of solar thermal energy in an industrial process. This includes acquiring knowledge of the process, development of energy efficiency measures and the implementation of a solar heating plant. Using this example, some of the main technical barriers of the dissemination of solar process heat in breweries are outlined. Finally it is demonstrated that the integration of a solar process heat plant in the brewing process is possible, although it seems difficult at first appearance due to its discontinuity. This integration was realized by a thorough analysis of the production process and its heat supply, combined with some modifications in the heat supply system.

## 1. INTRODUCTION

Climate change, scarcity of fossil resources and rising prices for oil, gas and electricity require a significant increase in energy efficiency and the use of renewable energies in all economic sectors (households, transport, industry, trade and services). The industrial sector is important, since it consumes nearly 30 % of the total final energy consumption in the EU 27 of which 67 % is thermal energy. Furthermore, a significant share of the heat consumed in this sector is in the low and medium temperature range as shown in Figure 1. Approximately one third of the industrial heat demand is required at temperatures below 100 °C and additional 27 % at temperatures below 400 °C.

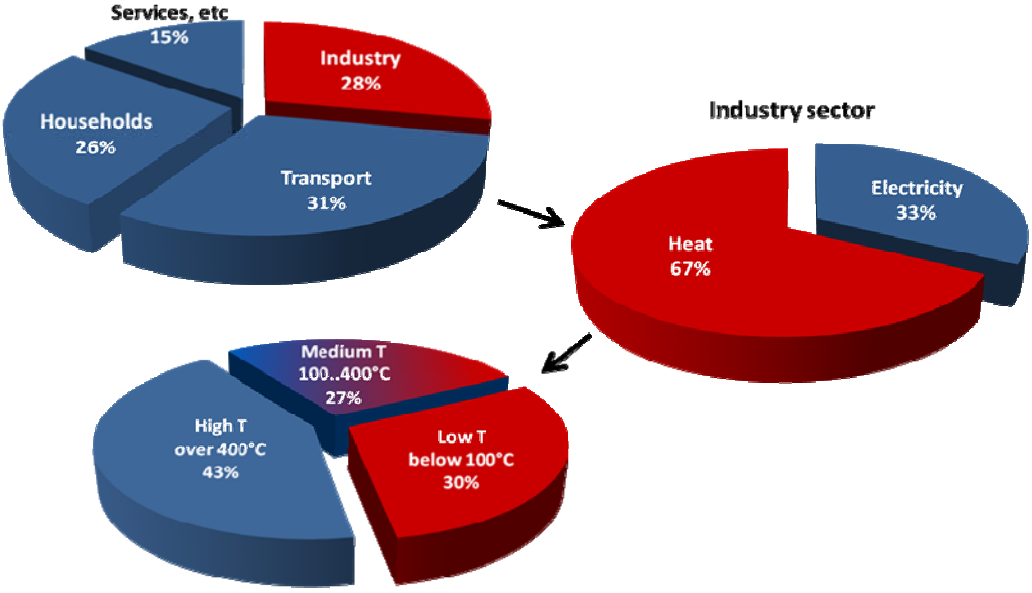


Figure 1. Final energy consumption in the EU 27 and

distribution within the industrial sector (Werner, 2007)

By the end of the year 2007, approximately 147 $GW_{th}$ of solar thermal collectors had been installed worldwide. Most of the installed systems are used for domestic hot water preparation, space heating or swimming pool heating (Weiss et al., 2009). Within the framework of IEA SHC Task 33/IV, the potential for industrial applications within the EU 25 was estimated to be between 100 and 125 $GW_{th}$. So far, approximately 90 solar heating plants with a total capacity of 25 $MW_{th}$ are used for industrial applications, which is a nearly negligible share of 0.02 % (Vannoni et al., 2008).

The food and beverage industry is one of the key sectors for solar heating, since processes such as cleaning, drying, pasteurisation, sterilisation or boiling take place at a low temperature level whereas the overall energy consumption is large (Brunner et al., 2008). Within the food and beverage sector, breweries show a large heat demand at relatively low temperature levels, but also a large potential for heat recovery. The brewing sector is also interesting because of the large number of breweries in Europe, especially in Germany. Almost 85 % of all German breweries are small and medium sized enterprises (SME) with an annual beer production of 5,000 m³ or less (Ernst & Young, 2006). This shows the significance of the investigated Hütt brewery, a case study in this paper.

Staudacher and Buttinger (2005) suggest that the application of solar thermal energy in a brewhouse is not suitable in many cases, due to the high temperature level necessary and the discontinuous heat demand. Nevertheless, the brewhouse needs large amounts of fresh water on temperature levels between 60 to 80 °C which can be preheated by solar energy.

This paper discusses some of the main technical barriers for the implementation of a solar process heat plant, taking the Hütt brewery as an example. In this context it shall also be shown that it is possible to integrate solar thermal energy in a brewhouse. A reasonable concept for the integration of a solar heating plant can only be achieved by a thorough analysis of the production process and its heat supply and sometimes a modification of the existing heat recovery or heat supply system.

## 2. IMPLEMENTATION OF A SOLAR PROCESS HEAT PLANT

The author’s general approach for integrating solar energy in an industrial process is to consider energy efficiency measures to reduce the energy consumed by all process steps, before considering solar process heat.

The major reason for this approach is that only a combination of energy efficiency measures and solar process heat can reduce the industrial energy consumption significantly, which should be the overall target. Another reason is that most energy efficiency measures have very short pay back times and can contribute to the general acceptance of a project. The consideration of efficiency measures can support the realization of a cost-effective solar thermal system. Therefore it is essential, that a detailed and comprehensive analysis of the procedural steps and the energy supply of the process are carried out.

This approach helps to identify untapped efficiency potential, provides important process data and helps to find an appropriate point for the integration of solar heat. Furthermore, the consideration of efficiency measures and heat recovery avoids the over-dimensioning of the solar heating system and it might be possible to lower the temperature level of a process which favors the integration of solar process heat. However, this approach needs a detailed understanding of the industrial process which increases the planning effort of a solar process heat plant.

This chapter will demonstrate this approach with its steps of acquiring knowledge of the process, development of energy efficiency measures and the implementation of a solar process heat plant, taking the Hütt brewery in Kassel as an example. In this description the major technical barriers for planning of a solar thermal plant are identified.

## The Hütt brewery

The Hütt brewery in Kassel produces approximately 8,000 m³ of beer per year and has an annual final energy consumption of 6.5 GWh. More than 80 % of the energy is supplied by natural gas and used to provide process heat, hot water and space heating. All heat consumers are connected to a steam network that is fed by a boiler (P = 2.6 $MW_{th}$). The production process is operated on five days per week in one shift. During summer, the amount of produced beer increases by a factor of 1.3 compared to the winter period. Based on their production capacity, technical installations and energy consumption, the Hütt brewery is a representative example for a typical SME in the brewing sector. The continuous development over the last decades with structural alterations and technological changes led to a non-optimised combination of production sites, installation and energy supply.

## The brewing process

For evaluating the feasibility of a solar thermal plant in industry, the process procedure, its energy consumption, and supply of individual process steps have to be analyzed. Since these data is rarely available in the required quality and also other options such as heat recovery have to be taken into account, there is still a very high and individual planning expense. This is a major barrier. Independent from the specific characteristic of a brewery, the production of beer can be divided into three parts: brewing, fermentation/storage, and filling of bottles, kegs or cans. Figure 2 shows the simplified scheme of the production process at the Hütt brewery.

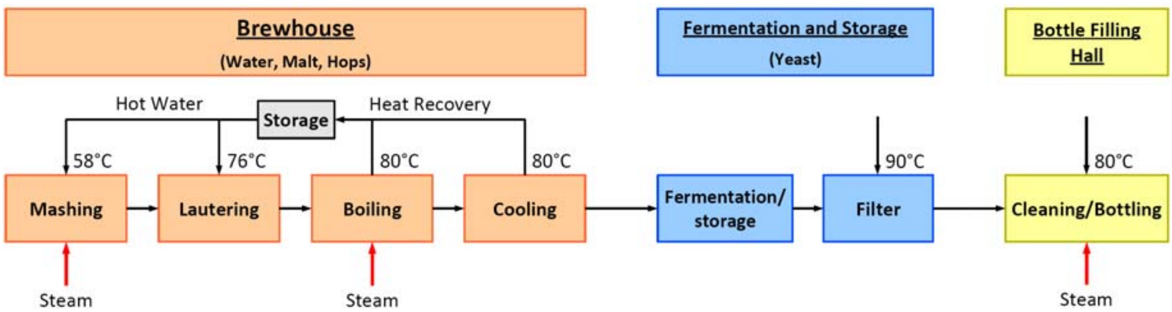


Figure 2. The brewing process

At first, the wort is produced within the brewhouse by mashing, lautering, and boiling. After cooling the wort, it is stored in the fermenting cellar. Once fermented, the beer is filled into bottles and kegs. Within the production process, the brewhouse has a share of 40 to 50 % of the overall heat consumption. The bottle and keg filling hall, with the bottle washing machine as biggest consumer, requires about 20..30 % of total heat demand (Staudacher and Buttinger, 2005). Besides a small amount of hot water for filtration, there is no significant heat demand within the process step fermentation and storage. However, this part is characterised by high electricity demand for cooling.

Two 50 m³ storages are installed at the Hütt brewery for the hot water supply of the brewing process described above. One has a constant fluid volume of 50 m³ whereas the other has a variable amount of water stored. This is necessary because of the dismatch between incoming hot water from heat recovery and outgoing water to supply several process steps.

The temperature level in the fixed volume tank is at 80 to 90 °C and slightly higher than in the variable volume tank at 60 to 80 °C as shown in Figure 3. The hot water needed for mashing and lautering is provided by the fixed volume tank and can be, if necessary, cooled down by mixing it with cold water at 10 °C. Additionally, this tank supplies the bottle filling hall with hot water at 80 °C, which is necessary for cleaning of cases and filters. The stores are fed by two heat recovery installations. After boiling, the wort is cooled in a counterflow heat exchanger by cold water, and the heated fresh water flows directly to the variable volume tank. During wort boiling, the evaporated water is condensed and either cold water is heated up to 80 °C, again flowing to the variable volume tank, or water from the fixed volume tank is heated up in a closed circle. This is controlled manually by the staff. A steam driven auxiliary heater is installed at the fixed volume tank as back up heating. The tank has an auxiliary volume of 30 % of its volume which is kept above 80 °C. The steam is provided by a central steam network.

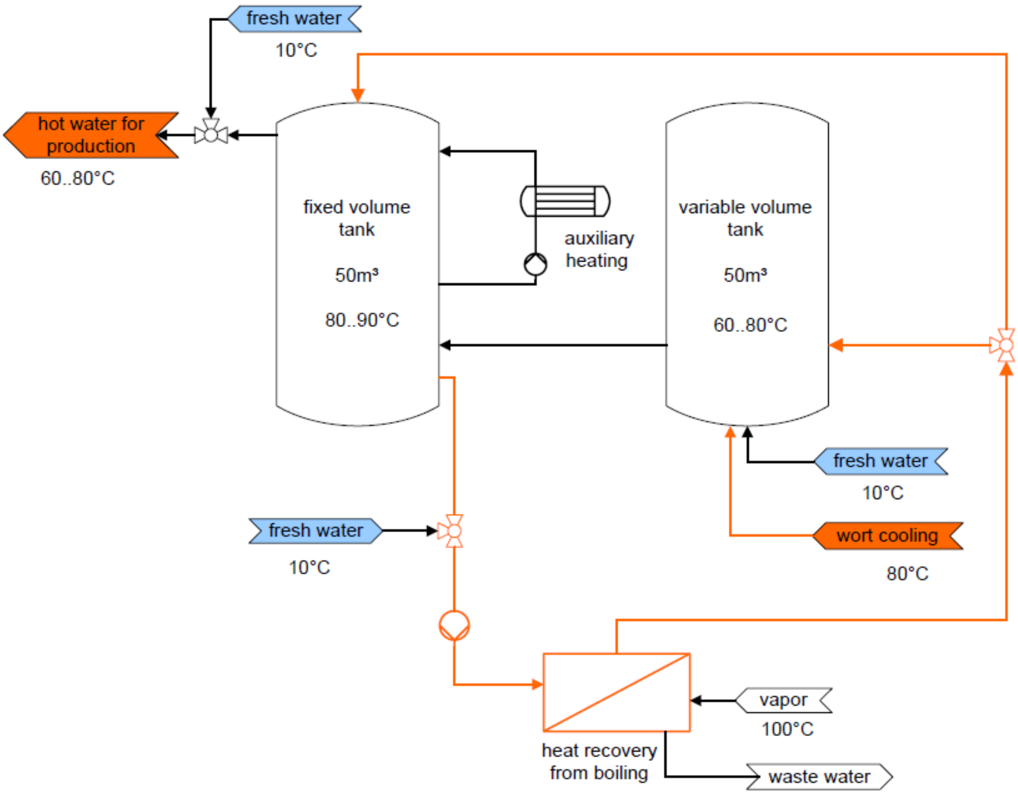


Figure 3. Initial hydraulics of the brewhouse at the Hütt brewery

All this procedural knowledge is required to plan a solar process heat plant, but it is difficult to get this information in a short time to keep the planning economical. Often even the company staff cannot supply the desired data and time consuming measurements are necessary. These facts can be seen as a further barrier for the dissemination of solar thermal plans in industry.

**Energy efficiency measures and process changes**

At the beginning of the research project at the Hütt brewery, all hot water consumers were supplied by the fixed volume tank with a higher temperature level. To achieve the process temperatures of 58 °C for mashing and 76 °C for lautering, hot water was mixed with a large quantity of cold water, because of the high temperature in the upper part of this tank (up to 90 °C). This is not a problem as long as energy is provided by fossil fuels. But as soon as solar energy is taken into consideration the temperature level plays a major role for the efficiency of the system.

Reducing the use of fossil fuels is the major aim when applying solar energy and process steps using steam need to be identified. In this system, steam provided by a steam network and produced by an oil fired steam generator, is used as a back up for the fixed volume tank. Figure 2 shows that steam is used for heating the wort during mashing. As this cannot be avoided, the back up of the fixed volume tank remains as major possibility for saving fossil fuels.

Although the wort boiling cannot be supported by solar process heat, it is possible to preheat the wort before boiling, so the heating by steam starts at a higher temperature than 76 °C. Therefore a heat exchanger was implemented which heats the wort before it is pumped into the boiling copper, as shown in Figure 4.

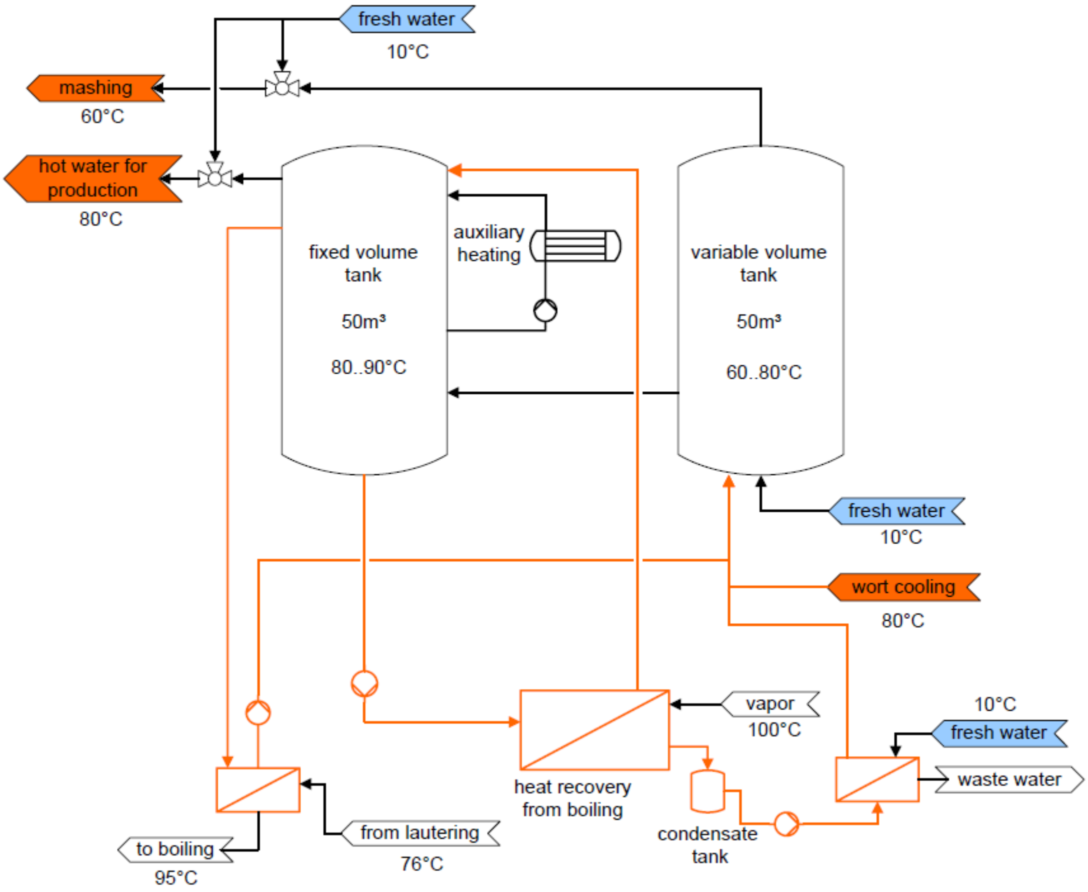


Figure 4. Implemented energy efficiency measures at the Hütt brewery

The hot water for heating up the wort is taken from the upper part of the fixed volume tank and fed into the variable volume tank afterwards. The variable volume tank always provides water to the fixed volume tank to keep it filled. The preheating of the lauter wort before boiling is most efficient if sufficiently high temperatures can be provided by the fixed volume tank. To achieve a high temperature level in the upper part of this tank it seems useful to supply the process step with the lowest temperature level, the mashing at 58 °C, from the variable volume tank which has generally a lower temperature level. Another improvement to support the preheating of wort, is to always heat up the fixed volume tank instead of producing hot water for the variable volume tank. Due to this change, the heat recovery is partly shifted to a higher temperature level and less hot water is produced, which can be provided by solar energy at a lower temperature level. Another measure to increase energy efficiency is to recover heat from the condensed vapour during boiling, as this is at a considerably high temperature level of almost 100 °C. Approximately 3 m³ per day of hot water can be produced directly by this heat recovery and is fed into the variable volume tank. The implementation of the energy efficiency measures described in this section represents a major barrier for the overall project, as convincing the staff and management of a company can be very difficult. It is especially difficult to communicate the awareness of the importance of the temperature levels of both, the heat recovery and the solar thermal system.

## Integration of a solar thermal plant

After implementation of the described efficiency measures within the hot water supply system, the solar plant has to be integrated in the process. At first sight the two 50 m³ tanks seem to offer a good possibility to connect a solar plant directly without an additional buffer tank. A first approach was to connect the solar plant to the variable volume tank. However, the fully mixed temperature level of 60 to 80 °C would lead to low collector efficiency. Another approach was to implement a direct flow system to heat up the cold water directly that is necessary to keep the variable volume tank at a certain level. This concept could not be implemented due to the load profile of the process. Large quantities of hot water are required at night time and during morning hours and the variable volume tank has to be refilled with fresh water to stay above a minimum level. Due to these facts, the decision was made to install an additional buffer tank for the solar heating system, as shown in Figure 5. Although a suitable concept for the system was found, the retrofitting effort for the integration of the solar system into the overall system, represents another barrier.

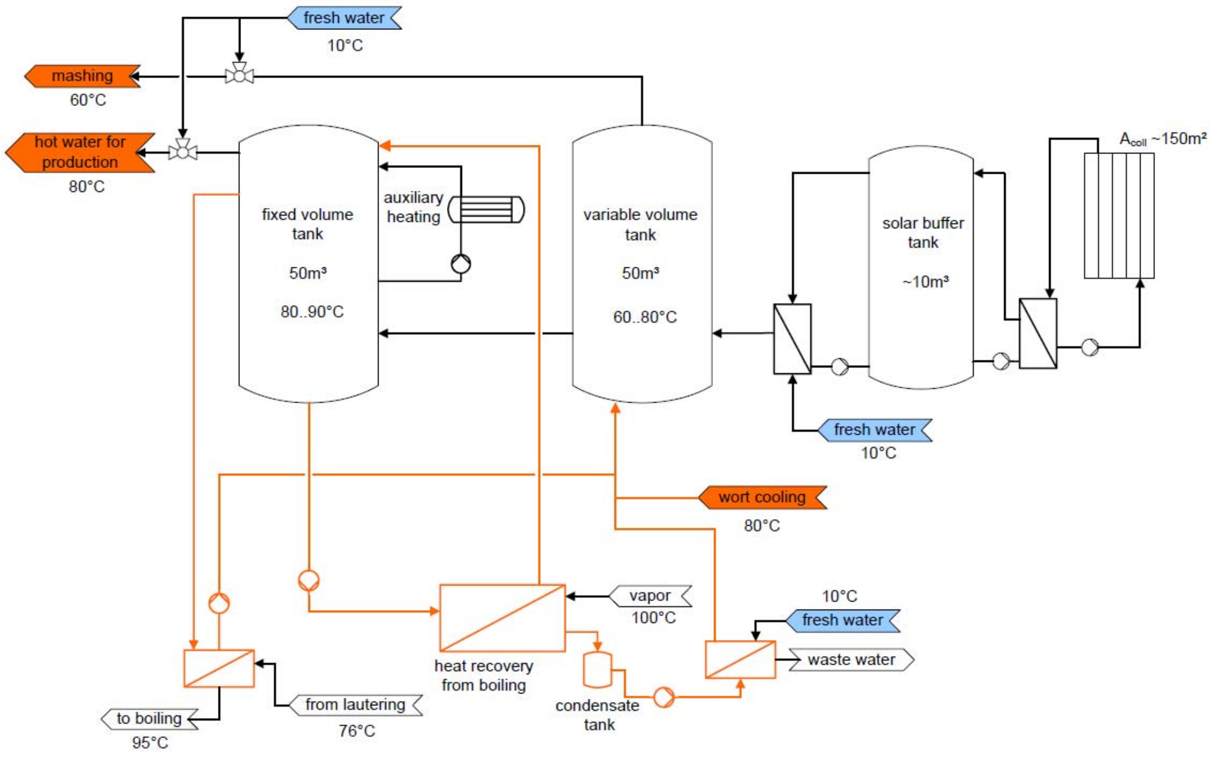


Figure 5. Integration of a solar plant into the adjusted system

This design leads to a simple system control and fresh, heated up water can be supplied to the variable volume tank if its volume falls below a certain level. In a first step of planning the solar plant, a TRNSYS deck was set up to simulate the processes in the brewhouse. The first challenge for setting up the TRNSYS deck was the definition of several loads and heat recovery sources. To overcome this problem, several load and heat recovery profiles were created based on the production protocols provided by the staff of the Hütt brewery. With these protocols it was possible to determine the volume flow rates and durations of the different loads. Finally, two different load profiles were created with different temperature levels for mashing at 60 °C and lautering and bottle filling hall at 80 °C. Based on these profiles, two more profiles for heat recovery were created. These different profiles are necessary because of different temperature levels for wort and condensate cooling at 80 °C and for condensation of steam during wort boiling at 98 °C. The fifth profile was created to consider the preheating of wort before boiling. This profile determines the times at which preheating of wort occurs and the actual temperature in the upper part of the fixed volume store is used as an input for the heat exchanger for preheating of wort. The lack of a quick possibility to create load files to simulate industrial processes is a major barrier for standard planning of solar plants for industry. A possibility to overcome this is seen by the authors in developing a tool for creating load files with the help of statistical functions and additional boundary conditions as it was done for domestic hot water purposes by (Jordan and Vajen, 2005). Altogether, the simulation of a system consisting of solar heating plant and the respective industrial load has been very time consuming. To date, the simulation of such systems is not possible with easier and faster simulation tools, this can be seen as an additional barrier for the economical planning of solar thermal plants for industrial processes. After creating the simulation model of the system at Hütt brewery, simulation results were used to dimension the collector field and solar buffer tank by determining the maximum amount of energy, which can be delivered by the solar thermal system to the hot water storages while avoiding stagnation in summer. This design ensures a high specific collector yield and resulted in a collector array of $A_{coll}$ = 150 $m^2$ and a volume for the solar buffer tank of $V_{sol}$ = 10 $m^3$.

## 3. SUMMARY

The application of solar thermal energy for industrial applications has a huge potential of 100 to 125 $GW_{th}$ within the EU 27. This huge potential is based on the facts that the industrial sector consumes nearly 30 % of the total final energy consumption in the EU27, and 38 % of that energy consumption is for thermal use in the low and medium temperature range.

The general approach for integrating solar energy into an industrial process should be to consider energy efficiency measures first, and consider solar process heat afterwards. The major reason for following this approach is that only a combination of energy efficiency measures as e.g. heat recovery and using solar process heat can reduce the amount of energy consumed by industry significantly, which should be the overall target. It seems not reasonable to just build a solar plant for providing heat to an inefficient process.

It is demonstrated that the integration of a solar process heat plant in the brewing process is possible, although it seems difficult at first appearance, due to its discontinuity. This integration was realized by a thorough analysis of the production process and its heat supply combined with some changes of the heat supply system.

The description of the integration of solar thermal energy in the brewing process at the Hütt brewery leads to some of the main barriers for the realisation of demonstration projects. Among these are the facts that a lot of procedural knowledge is required to plan a solar process heat plant. So far, this is difficult to be achieved in adequate time to keep the planning economical. Often even company staff cannot supply the desired data and time consuming measurements are necessary. Convincing the staff and management of a company represents another major barrier for the implementation of necessary energy efficiency measures. Especially the awareness for the importance of temperature levels of both heat recovery and solar thermal system is difficult to mediate. An additional barrier is the rebuilding effort for the integration of the solar plant into the overall system. The lack of a quick and safe possibility to create files for simulation of industrial loads is a further technical barrier for standard planning of solar plants for industry.

## 4. ACKNOWLEDGMENTS

The authors gratefully acknowledge the financial support provided by the Reiner-Lemoine-Stiftung and the German Federal Ministry for Environment, Nature Conservation and Nuclear Safety, contract No. 0329601T. Additionally, we would like to thank the Hütt brewery (esp. K.-P. Reinl) and GEA Huppmann (esp. Dr. L. Scheller) for the close collaboration within this research project.

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