projektinfo 13/10

BINE Informationsdienst

Brewing beer with solar heat

- Breweries provide good conditions for utilising solar process heat
- Production times partly matched to solar radiation
- Water is the only energy transfer medium
- General concept being prepared for the industry

Fig. 1

The Hofmühl brewery in Eichstätt, Bavaria, deploys concentrating evacuated tube collectors. These enable high working temperatures.

Cleaning, drying, dyeing, pasteurising, bleaching and melting – at first glance, the potential for utilising solar process heat in industry seems enormous. The aforementioned selection of cross-sector processes is at least partly suitable for provision with solar thermal energy. Despite this, the number of applications that actually use solar process heat lags far behind its theoretical potential. This is partly due to the fact that this is a new application area for solar thermal energy. A closer examination shows, however, that the necessary system technology is relatively expensive for processes with operating temperatures above 100 °C. This technology will only be available after successful testing of pilot applications. At this temperature level, the low and inconsistent solar irradiance in Germany has also prevented more widespread use. In the low-temperature area below 100 °C, the technology is fully mature and the solar thermal systems are more efficient. The greatest challenge is integrating the systems within the complex array of different industrial processes.

The independent Hofmühl brewery in Eichstätt and the Hütt brewery in Kassel-Baunatal have risen to this challenge and support their brewing processes with solar thermal systems. This enables them to reduce their oil and gas requirements in the long term. Both research projects are not yet finally concluded. The first results will become available in 2011.

Breweries generally offer good conditions for integrating solar thermal energy. As with the rest of the beverage industry, they mostly require heat in summer when the most solar energy is available. For example, the Hofmühl brewery brews twice as much beer during the summer months than in winter. Furthermore, most process stages are conducted at a relative low temperature level and the heat requirement is distributed relatively consistently throughout the day and week. This means that no unnecessarily large storage tanks are required. Although all breweries brew beer according to the same basic principle, a closer examination reveals considerable differences in terms of the technical processes. That is also shown in the case of the aforementioned research projects, which have been subsidised by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety as part of its Solarthermie2000plus funding programme.

▶ Hofmühl brewery in Eichstätt

The operators already began reducing the brewery's energy requirements a few years ago. Using the so-called Merlin "gentle brewing" process, they were able to save around 60% of the previously used primary energy. The procedure is based on an evaporation process in which the "wort" (malt extract) is heated above a cone-shaped surface. Because this makes it much easier and quicker to remove unwanted aromas, the boiling process in the brew house has been reduced from 100 to 40 minutes. In addition, the operators also optimised the boiler, cooling and ventilation system, which also reduced the energy consumption. The installation of a solar thermal system is intended to reduce the previous heating oil requirements even further.

835 square metres of evacuated tube collectors can currently be seen on two historic buildings and a newly built warehouse belonging to the brewery. These are directly installed on the roofs or on mounting frames. The array sections face southwest and the collectors are tilted at angles of 23 and 26 degrees from the horizontal. The evacuated tubes are encased with parabolic-shaped reflectors. These compound parabolic collectors (CPCs) have the advantage that their optimally arranged focus points enable the mirrors to direct solar radiation onto the absorber tubes from different irradiance angles. The thermal energy generated is stored in two 55-m³ solar storage tanks. These are connected in series. The first storage tank is fed by the solar thermal system's return system and in turn feeds the second storage tank. Via heat exchangers, the second storage tank supplies the necessary energy to various process stages that require temperatures of up to 100 °C.

Solar-supplied process stages

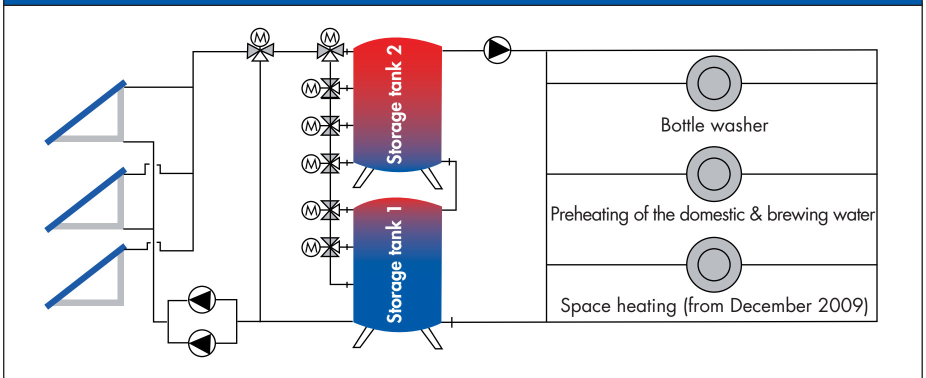
A maximum temperature level of 110 °C can be provided in the solar circuit. If the necessary temperature is available, the bottle washer is first of all supplied with 90 °C via a heat exchanger. The brewing and domestic hot water is then reheated in a temperature range between 90 and 60 °C and, if required, space heating is also provided within a range of 65 to 45 °C. The returning, cooled down heat transfer medium (water) is once again heated by the collectors and then temporarily stored in the two energy storage tanks. The storage tanks are capable of storing the energy volume generated from a summer weekend, with up to 115 °C for 110 m³. If temperatures are only available between 50 and 80 °C, the energy is only used for heating domestic and brewing water, space heating and providing frost protection. The preheated brewing water can be used for various steps in the brewing process (see "The way to a refreshing pint").

The sunshine duration determines production times

According to the operators, the brewery does not have to maintain constant production during the week but, within certain limits, can determine the brewing times according to the solar irradiance. This led to the system operators introducing a solar-dependent process control.
The production is increased when there is a lot of sunshine and is throttled back when there is low irradiance. The volume of water circulating through the collector array also varies depending on the irradiance duration and intensity. If there is little sunshine, the volume of water in the circuit reduces. This enables the water to reach the desired temperature relatively quickly and, even if there is low irradiance, the solar thermal system can still produce heat at the required temperature level, if only in small amounts. If there is a lot of sunshine, the water volume is correspondingly increased. This "matched flow" regulation enables the operators to reduce energy storage costs in the long term.

Fig. 2: Mounting one of the 55-m³ solar storage tanks

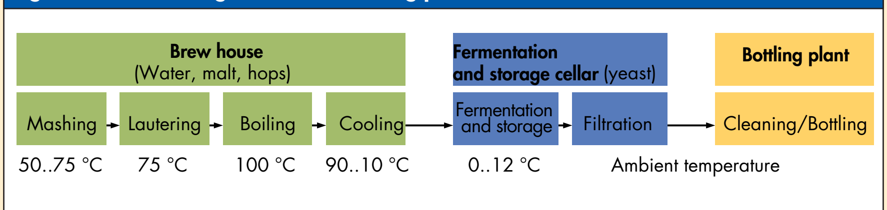
Fig. 3: Schematic of the solar thermal system



The way to a refreshing pint

The production of beer can generally be divided into three stages: the production of "wort" (malt extract) in the brew house, its subsequent fermentation and storage, and the filling of barrels and bottles. The wort is produced in the brew house by means of mashing, "lautering" (separation) and boiling, whereby mashing and lautering require very large amounts of hot water. This means that around half of the thermal energy used by a brewery is required in the brew house. However, much of the heat supplied in the brew house can also be recovered. For example, the cooling of the wort generally produces precisely the right amount of hot water for the mashing and lautering processes. Additional heat recovery mostly occurs during the boiling process when the evaporated wort is condensed.
Around a quarter of the total thermal energy is required in the bottling plant, since the barrels and bottles must be cleaned before being filled. The rest of the heat consumption is divided between other cleaning and sterilisation processes and the building heating. The fermentation and storage cellar requires considerable electricity because the fermentation and conditioning processes take place at low temperatures where vapour-compression chillers are used. Here there is potential in future to meet the necessary cooling requirements, and thus save electricity, using chillers (absorption, adsorption) operated by solar thermal energy.

Fig. 4: Schematic diagram of the brewing process



Energy transfer medium without antifreeze

Instead of the usual water-glycol mixture, the system operators use water as the sole energy transfer medium. This enables them to optimally use its thermal properties. Water can transport more thermal energy than a corresponding mixture with glycol antifreeze. This saves on having to use additional heat exchangers. An active frost protection system is used instead. When the solar irradiance is insufficient to prevent freezing, minimum circulation occurs via the colder storage tank (store tank 1). This prevents the pipes and collectors from freezing up. When this is in operation, the drive pump runs on the lowest power setting. Nevertheless, Chemnitz University of Technology is keeping a close eye on the energy consumed as a result. By means of continuous measurements, they are checking whether the energy required for the circulation operation is viable in the long term. If this is the case, this could provide additional benefits. For example, if the heat transfer medium is lost, the system can be simply refilled with cheap water.

▶ Hütt brewery in Kassel-Baunatal

As a first step, the scientists at Universität Kassel drew up an energy audit. Based on this, they then determined measures to increase the efficiency. The core process here is the wort boiling. The operators converted this to an evacuated boiling system and now save around a third of the energy they previously required. The internal heat recovery was also optimised. The waste heat from the boiling process is now used in a closed circuit for preheating the wort from 75 to 95 °C. This heating was previously achieved using steam, which can now be dispensed with. The improvement measures also reduced the amount of low-temperature water resulting from the heat recovery. However, since all breweries have fixed hot water requirements, this created a "supply gap". This has been met by installing the solar thermal system.

The concept behind the solar thermal system

A 155-m² array comprising southwesterly facing flat-plate collectors generates part of the thermal energy required for supplying hot water. A water-glycol mixture is used as the energy transfer medium. The energy is transferred to a 10-m³ buffer storage tank. This is used to heat the cold brewing water from the supply tanks to a maximum of 90 °C. The water is heated via an external plate heat exchanger. The solar-heated brewing water is then fed into the drawdown tank when its fill level drops below a certain level. However, it can only be filled to 80% of its capacity, since this storage tank is additionally filled with hot water produced using heat recovered during the wort cooling process. Corresponding volumes must be kept free during the production times from Sunday evening to Friday noon. The drawdown tank releases hot water to the displacement tank and also supplies the mashing process, which only requires relatively low temperatures of just under 60 °C. During production-free periods, the drawdown tank can be completely filled with solar-heated brewing water.

The brewing process alternates between phases in which hardly any thermal energy is required from the tanks and phases in which a considerable amount of thermal energy is required very quickly. The displacement tank supplies hot water to the main process stages, including lautering, the lauter wort heating and other processes (bottling, filtration and cleaning). Because these all require relatively high temperatures of around 80 °C, it is important that the displacement tank is always kept full.

Intermediate report

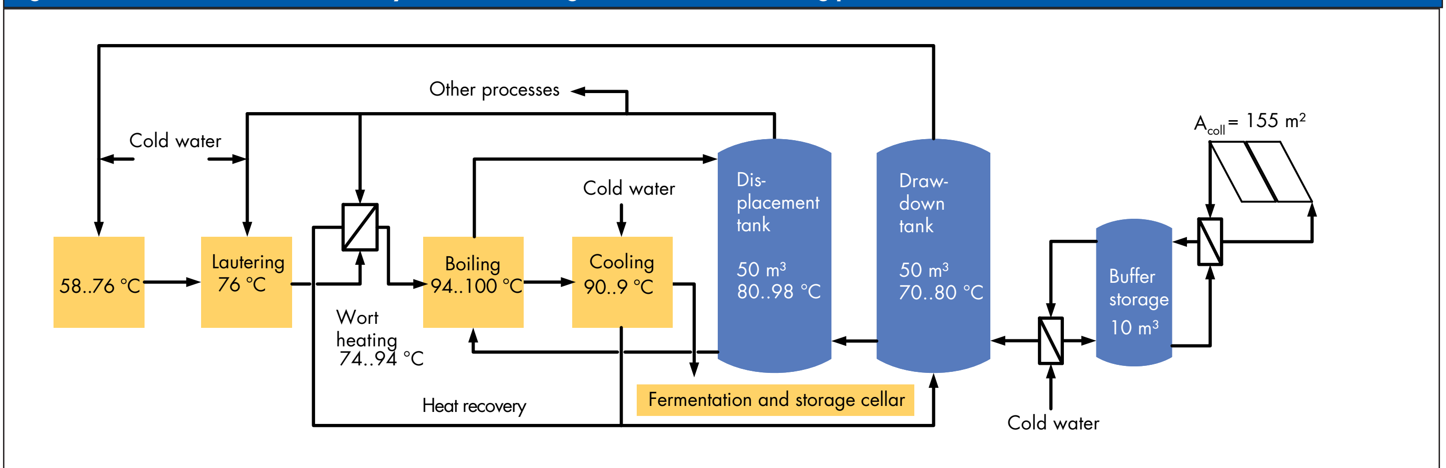
The solar thermal system began operation in May 2010. A uniform approach has been taken throughout the entire research project. A detailed analysis of the current situation was followed by measures to increase

Fig. 5: The collectors have a tilt angle of 30°

the efficiency and the integration of the solar thermal system. Continuous measurements are already being conducted to monitor and optimise the interaction between the solar thermal system and the hot water supply. By monitoring the energy in detail it is also planned to identify weak points and improve the energy efficiency. There is still no supply line from the drawdown tank for the mashing process. This is currently supplied by the displacement tank. It is planned to lay this line by the end of the year and install additional measurement technology in the brew house.

The declared aim of the researchers is to develop a general industry concept to enable the scientific findings to be used for other breweries. A total of around 95,500 euros have been invested in the solar thermal system, which amounts to around 600 euros for each square metre of collector surface area.

Fig. 6: Schematic of the solar thermal system and its integration within the brewing process



▶ Conclusion and outlook

The provision of solar process heat for industrial applications is not yet widely established. Solar thermal heat is still principally used for solar hot water and space heating for temperatures between 35 and 60 °C, whereby the efficiency characteristic curve and thus the economic viability of solar collectors decrease with increasing operating temperatures. However, if more efficient process heat collectors are developed, this should improve the viability of process heat in the long term.
At the Hofmühl brewery in Eichstätt, the CPC collectors have enabled the energy storage medium to be heated at times to 120 °C. However, they have not yet supplied any process stages above 100 °C with solar heat. The Hütt brewery initially set the bar much lower. The brewing stages that are supposed to be supplied with solar heat are all at a temperature level below 80 °C. This has the advantage that the processes can also be supplied with solar heat when there is low solar irradiance. The solar share of fraction is in the single-figure percentage range.
In principle, there are interesting possibilities and considerable potential for using solar process heat in Germany. Initial pilot projects such as the two aforementioned breweries, but also existing systems in metal processing industries, delicatessen production, laundries and car wash installations, demonstrate that solar process heat is technically viable. Its widespread use is possibly being hindered, however, by the fact that there is still a considerable lack of pilot systems – and thus the necessary operating experience – not only in Germany but also throughout Europe. The incorporation of solar thermal energy into existing production processes is considerably more complex and detailed energy analyses and concepts are required. In order to successfully increase the use of solar process heat, it will be necessary to reduce the considerable planning effort required. In specific terms, this means developing process and industry concepts and standardised system solutions that include, among other things, planning guidelines for the respective type of application. Here the scientists at Universität Kassel are moving in the right direction.

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Literatur (in German)

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Internet

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- Figs. 1, 2: Krones AG Neutraubling/ Hofmühl-Brauerei Eichstätt
- Fig. 3: Chemnitz University of Technology
- Figs. 4-6: Universität Kassel

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Project Number
Hütt-brewery: FKZ 0329609E
Hofmühl-brewery: FKZ 0329609D

IMPRINT

ISSN
0937 – 8367

Publisher
FIZ Karlsruhe
76344 Eggenstein-Leopoldshafen, Germany

Editor
Birgit Schneider

BINE Information Service Energy Expertise

BINE Information Service provides information on energy-efficient technologies and renewable energy.

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BINE is an information service by FIZ Karlsruhe, which is promoted by the Federal Ministry of Economics and Technology (BMWi).

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Supported by:

Federal Ministry of Economics and Technology

on the basis of a decision by the German Bundestag

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