SOLAR PROCESS HEAT APPLICATION AT THE HOFMÜHL BREWERY AT EICHSTÄTT / GERMANY

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1. Introduction

The Hofmühl brewery solar project demonstrates the use of solar energy for process heat applications at temperature levels above 100 °C. The results can be used for high temperature solar energy applications in other brewery companies or other sectors of industry in the future.

2. Project overview

The Hofmühl brewery in the Altmühltal is a small private brewery in Eichstätt with a beer production of approx.8.000 m³ per year. Before the installation of a solar plant the brewing process was already optimized and an energy-saving brewing technique was introduced, which is reducing the energy consumption by more than 60 %. Previous to the installation of the solar thermal plant in July 2009 the annual consumption of 7.920 GJ of primary energy for process heat, hot water and space heating was supplied by oil. The beer is produced to two thirds during the summer period, so that energy supply and energy demand synchronize. Additionally the process management was adjusted to the supply from solar energy so that energy costs can be drastically reduced. The energy that is gained from the solar system is used at several positions with different temperature levels in the brewery and production process as well as for the space heating.

After creating the necessary foundations two solar storage tanks, each $55m^3$, were installed in April 2008. The solar system uses pure water as heat transfer medium, therefore it is necessary to provide an active freeze protection in the winter months. Neither the installer of the solar plant nor the operator at the brewery had had experience with the freeze protection of a pure water system at that time. So in October 2008 a first smaller test collector field from vacuum-tube collectors with water as heat transfer medium was put into operation. Using only solar energy stored in the buffer tanks, the active freeze protection was tested on a first field during winter 2008/09. In spring 2009 the collector field was installed and at the same time the two loads bottle washing machine and the heating of brewing and process water were connected using the already existing ring main. Currently there are three sub fields installed with an overall aperture area of 735,5 m2. All subfields are oriented south-west (52°) and the collector inclination is 23° respectively 26° from the horizontal. In November 2009 the space heating was integrated as an additional load (fig.1.). The outlet flow of a load with a higher temperature level can be used as inlet flow for loads with a lower input temperature needed.

Because the space heating as the connected load with the lowest temperature requires at least 60°C, a solar support is not possible at lower storage temperatures. For freeze protection the warm water in the storage tanks is pumped through the collector field. Should the temperature in the storage tanks decrease under a critical value in winter a conventional reheating is possible using the heat exchanger of the brewing and process water preheating.

The start up of the measurement and the data transfer of the measured values to the university took place in June 2009.

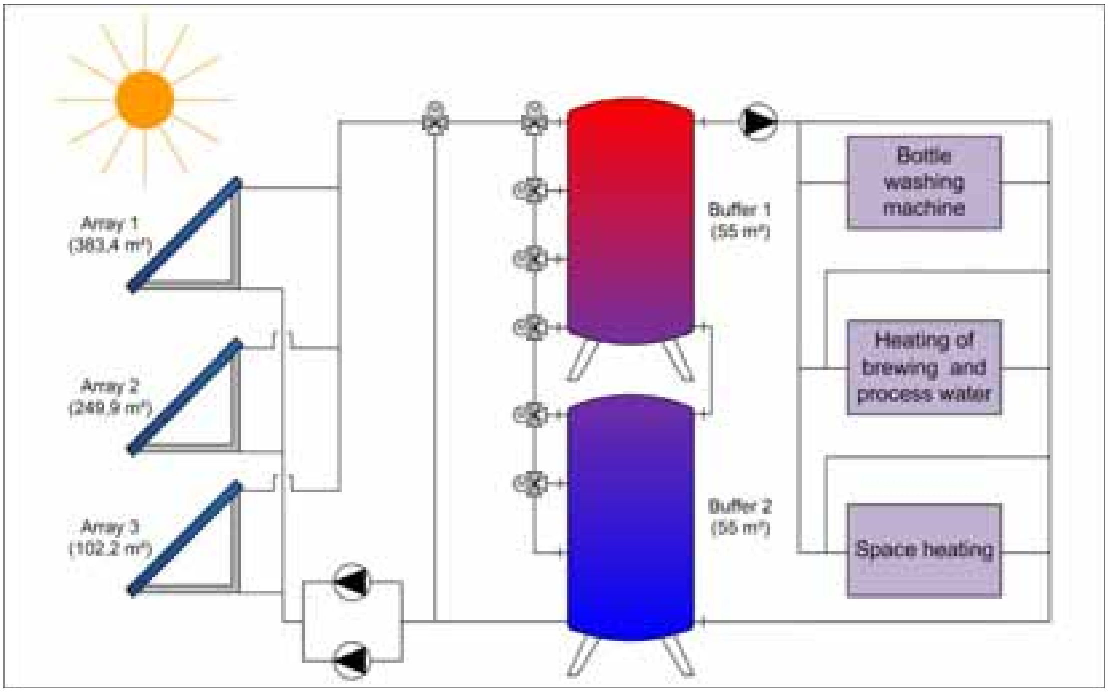

Fig. 1: Scheme of the solar process heat application

Fig. 2: View on Hofmühl Brewery with the collector arrays

Fig. 3: View on the collector arrays (left) and the storage tanks (right) in July 2009

3. Monitoring results

3.1. Summer operation

The July 2010 can be seen as a representative moth for the summer operation at the location Eichstätt. The balance shows that about 40% of the irradiated energy is transformed into thermal energy at the collector. During the month the stores are charged with about 189,8 GJ. The averaged temperature in the upper store area is about 105 °C. This is sufficient to serve the bottle washing machine and the heating of brewing and process water. At low irradiation (in the morning, at overcast days) about 16,6 GJ are used from the storages as start-up waste to heat the collector field to operating temperature. The following figure 4 shows the irradiation on the collector field, the collector yield and the amounts of energy that are used in the process in July 2010.

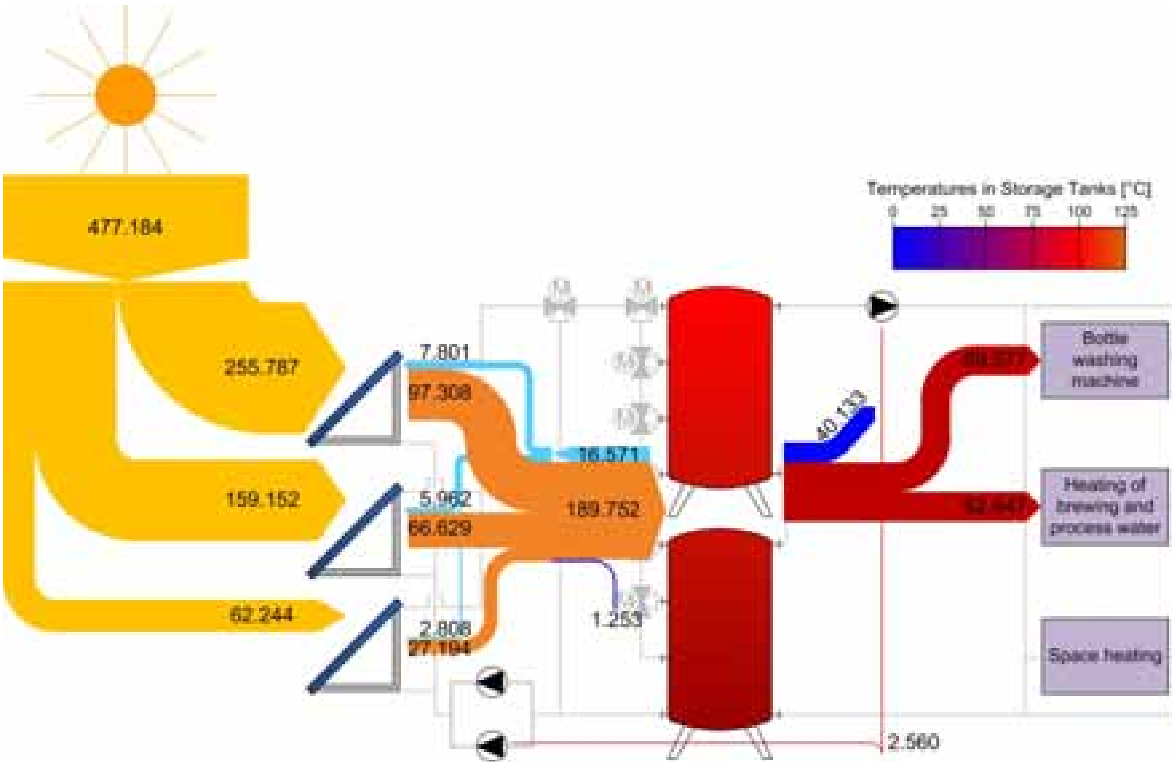

Fig. 4: Energy gain and storage temperatures in July 2010 [MJ]

Tab. 1: Percentage of total energy consumption provided by solar system for each load

Bottle washing machine	Heating of brewing and process water	Space heating	Freeze protection
32 %	38 %	-	-

When the efficiency is calculated for a complete collector field this efficiency will be lower than the efficiency of a single collector under standardized collector test conditions. Experiences show that this is in the range of 5 and 10 percentage points. The field-efficiencies of the single subfields were calculated in a reference period at the end of July 2009 lies between 3 and 8 percentage points under the theoretical efficiency of the single collectors under test conditions. Due to this small deviation and on the present data basis a good operation of the collector field can be assumed.

3.2. Operation in spring and autumn

Due to the decreased irradiation on the collector surface during the transitional period collector field outlet temperatures higher than 100°C are only rarely reached. As a result the temperature level in the upper store area decreases below the requirements of the bottle washing machine, so this load cannot be served using solar energy any more. The energy is used for heating the brewing and process water and space heating, since both require a lower flow temperature. At the same time in the transitional period the operating state freeze protection can occur. The amount of energy that is discharged from the storage tanks to the collector fields now consists of energy for the field preheating and the freeze protection.

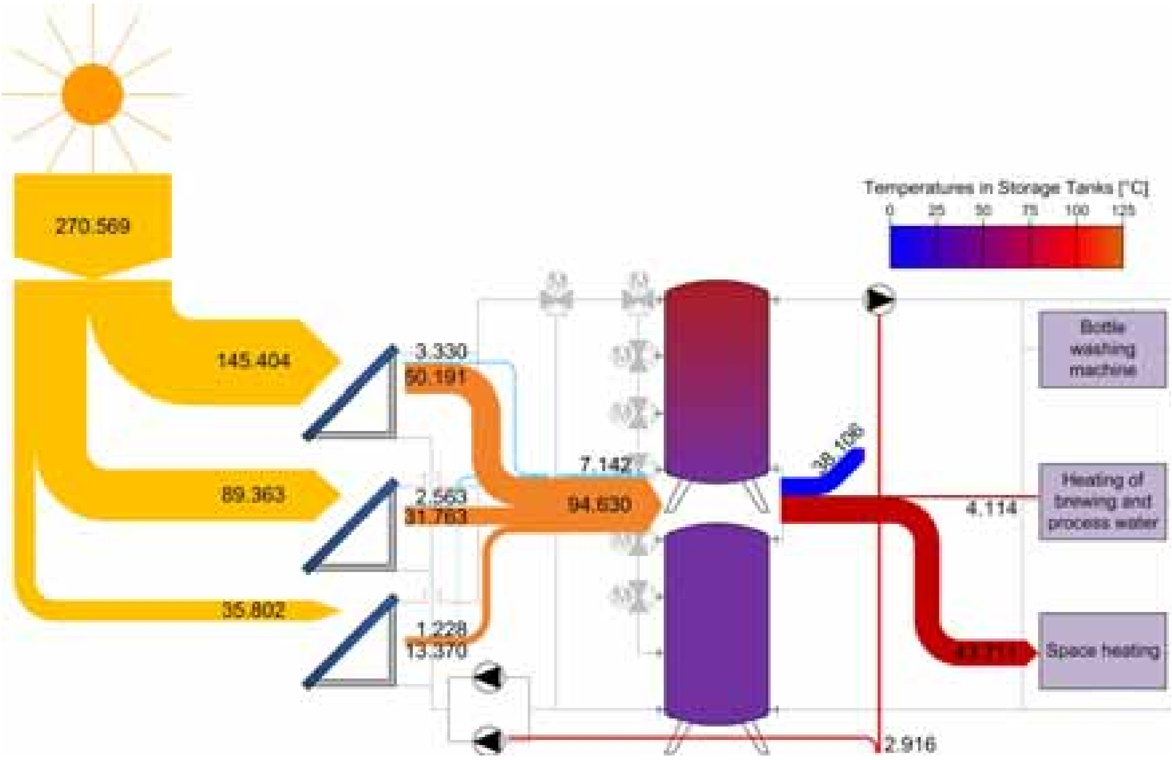

Fig. 5: Energy gain and storage temperatures in March 2010 [MJ]

Tab. 2: Percentage of total energy consumption provided by solar system for each load

Bottle washing machine	Heating of brewing and process water	Space heating	Freeze protection
-	2 %	35 %	100 %

3.3. Winter operation – Freeze protection

As a result of less solar radiation during winter time, the outlet temperature of the collector array is seldom high enough to provide energy at a useable temperature level. Therefore it is not possible to support the space heating system or the brewing processes. Because of low ambient temperatures the collector array is nearly permanently flown for freeze protection and the temperature in the buffer tanks decrease below 15 °C. A conventional auxiliary heating by using the heat exchanger of the brewing and process water heating was not necessary in both winters.

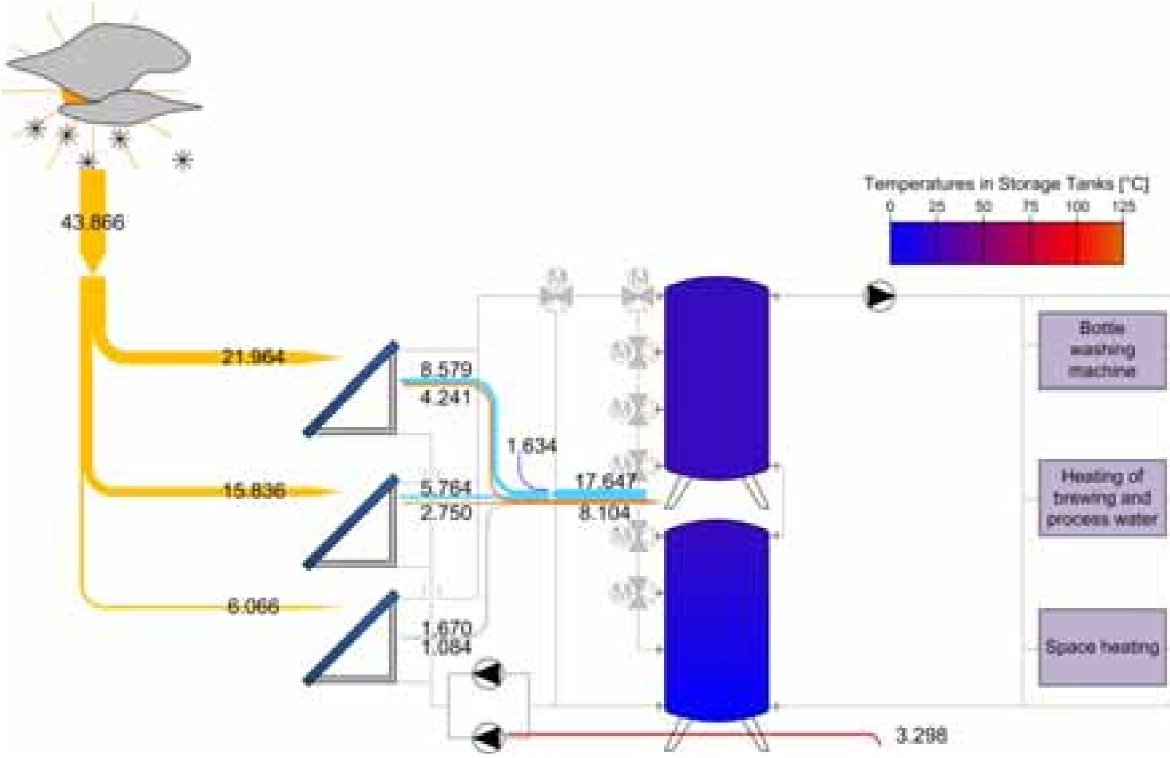

Fig. 6: Energy gain and storage temperatures in January 2010 [MJ]

Tab. 3: Percentage of total energy consumption provided by solar system for each load

Bottle washing machine	Heating of brewing and process water	Space heating	Freeze protection
-	-	-	100 %

4. Active freeze protection

At times of low ambient temperatures it is necessary to protect liquid flown solar collectors against freezing. Conventional solar systems use antifreeze liquids like glycol-water solutions. These solutions got two disadvantages. First there is a higher consumption of electricity for the circulation pumps. Second disadvantage is that this heat transfer mediums are not temperature resistant at temperatures over 150 °C in case of stagnation.

An equal flow all over the collectors in a collector field is an essential requirement for a reliable active freeze protection. The parts of the collector field which are less flown will freeze first. Reasons for uneven flow include air in the system or lack of hydraulic balance. Even a beginning of freezing has to be avoided, because freezing is a self reinforcing effect. The icing of pipes reduces the inside diameters and increases the pressure drop, so the flow rate will decrease even more.

If the collector field is heated with warm water from the buffer tanks for freeze protection the balance of the used thermal energy can be calculated on two different ways.

The first way is reducing the solar gain by the amount of thermal energy used for freeze protection. The thermal auxiliary energy for freeze protection is then equivalent to the energy taken from the storages to warm up the field.

The second way is applicable for solar systems using water as heat transfer medium. The freeze protection can be defined as a system specific load with a very low temperature level needed. Balances can be done equal to the other loads, which cannot be served because of the low temperature in the storage tanks. The thermal auxiliary energy for freeze protection is only the amount of energy which is provided by conventional sources. In the winters 2009/10 and 2010/11 was no conventional auxiliary heating necessary.

The electrical auxiliary energy for the freeze protection is in both cases the electricity used for the pumps.

Tab. 4: Energy consumption for freeze protection

	Winter 2009/10	**Winter 2010/11**
Thermal energy used for freeze protection	79.314 MJ	37.113 MJ
Electricity used for freeze protection	6.479 MJ	7.709 MJ

5. Summary of gain measurements

The following table shows the solar energy gain from two years of monitoring.

Tab. 5: Energy gain of the solar system

Energy gain		
	08/2009 - 07/2010	**08/2010 - 07/2011**
Radiation on collector surface	3.005 GJ	3.082 GJ
Collector gain	954 GJ	923 GJ
Storage input	941 GJ	909 GJ
Bottle washing machine	160 GJ	194 GJ
Heating of brewing and process water	317 GJ	232 GJ
Space heating	143 GJ	172 GJ
Electricity used	27 GJ	27 GJ
Specific gain of the solar system	**843 MJ/m²**	**814 MJ/m²**
Efficiency of the solar system	**20,7 %**	**19,4 %**
Specific use of electricity	**0,044 MJ_{el}/MJ_{th}**	**0.050 MJ_{el}/MJ_{th}**
Percentage of total energy consumption provided by solar system	**11,5 %**	**11,1 %**

6. Acknowledgments

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