ONE YEAR FIELD TEST EXPIRIENCE OF A SOLAR THERMAL ENERGY FACADE AT A COMMERCIAL BUILDING SITE

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1. Introduction

This paper presents the results of a one year monitoring phase for a new and holistic approach for the energetic renovation of commercial and industrial buildings. The approach is based on the application of a curtain wall concept, which includes heat insulation, heat production and architectural modernization. Therefore, the so called *SonnEn+ façade* was developed by three industry partners from the region North Hesse in Germany and in 2009/10 a pilot plant was built up. Several aims were taken into account:

- Architectural integration of the solar panels (attractive design)
- Full usage of building in renovation phase
- Easy revision, so that all components can be maintained from outside the building
- Holistic approach from the solar collector to the tank
- Economic amortization should be the same as for conventional standard solar systems

The pilot plant is fully monitored, especially the collector loop containing the triple-glazed façade collector field with an aperture area of 32 m^2. Measured data is sent automatically via email to a server, where it is written into a database. The collected data can then be analyzed by connecting to the database. The data transfer and analysis tool was implemented at Kassel University in cooperation with FSAVE Solartechnik GmbH. Beside functions (algorithms) which can be run automated there is a possibility to visualize the data in a web browser to examine the operation of the system. In this paper the visualization feature is presented more detailed. The results of a data analysis show the operating behavior of the system, e. g. stratification in the store, maximal temperatures in the different collector strings of the façade. In the beginning, there is a short description of the project installation and the monitoring concept.

2. Project Description

The façade of a building is the flagship of a building. Standard components of existing solar thermal systems for DHW production can only be plugged onto the wall and thus do not meet any aesthetic feelings. However, the new so called *SonnEn+ façade* combines innovative components, architecturally pleasing design and the use of renewable energies. The *SonnEn+ façade* was developed by a consortium consisting of Stahlbau Lamparter, Energy Glas and FSAVE Solartechnik. Not only the architectural and system design follows a new approach but also the main components are further developed from the state-of-art. The heating system consists of a full glass collector field with an aperture area of 32 m^2 being part of the façade and a 5 m^3 central heating buffer storage. The collector is a full glass collector without a frame developed by Energy Glas GmbH. The absorber itself consists of an aluminium roll-bond applied with an anti-reflective coating. The collector was tested according to (EN 12975, 2006). The test results prove that the façade collector can compete with conventional flat plate collectors (Heinzen, 2010). The buffer storage is a non-pressurized cubical and well insulated plastic tank developed and produced by FSAVE Solartechnik GmbH. As it is assembled on-site from several smaller parts it can be integrated in nearly every building. The container is insulated with a 120 mm thick polyurethane hard foam insulation. Figure 1 shows the installed energy façade as well as the implemented heat buffer storage. Domestic hot water preparation is carried out directly with an internal corrugated stainless steel coil. The solar thermal collector loop is connected to the system via an external plate heat exchanger and a stratification pipe inside the storage. The room heating loop is integrated via a return flow bypass (see also Figure 2 for the hydraulic scheme of the pilot plant).

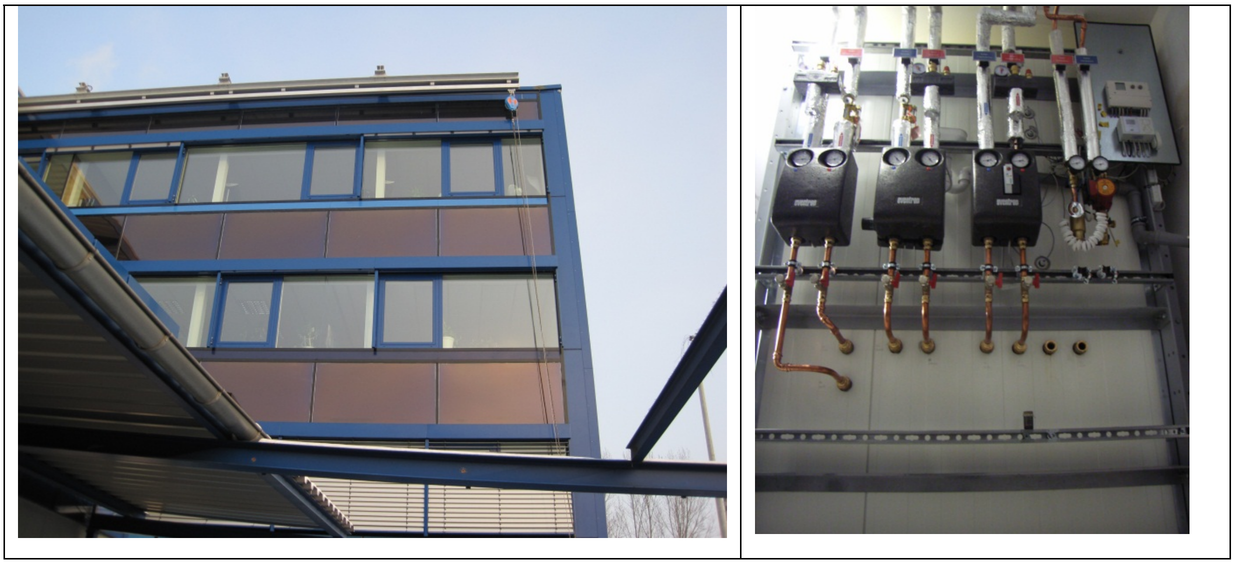


Fig. 1: Installed energy façade at the company site of Heinrich LAMPARTER Stahlbau GmbH & Co. KG (left) and installed heat buffer storage FLEXSAVE (right).

3. Monitoring Concept

The pilot plant is fully monitored in order to detect possible problems or malfunctions and thereby, to improve its performance or rather to refine the *SonnEn+ façade*. Flow rates and flow and return temperatures are monitored for the domestic hot water loop, the auxiliary heating loop and the room heating loop as well as for the primary and secondary solar loop. So, it is possible to calculate the different energy yields. In order to examine whether stratification in the store works as assumed, there are several temperature sensors installed at different heights in the store. Moreover, the ambient temperature as well as the irradiation in collector plane is measured. Figure 2 shows the hydraulic scheme of the pilot plant including positions of installed measuring equipment.

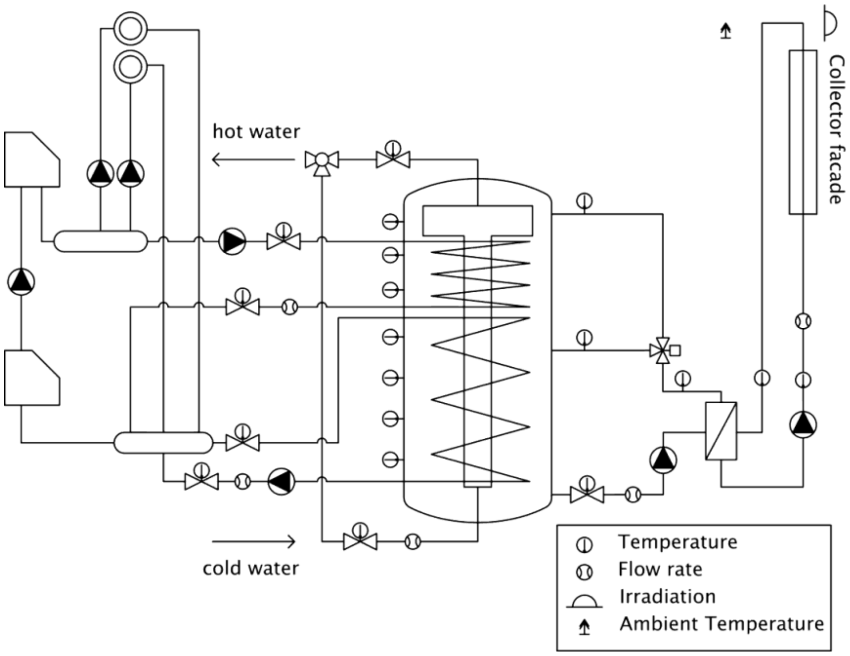


Fig. 2: Hydraulic scheme of the pilot plant, including installed measuring equipment. The several loops are equipped with sensors for measuring flow and return temperature as well as the flow rate. So, the different energy yields can be calculated. Moreover, irradiation in collector plane and ambient temperature are monitored.

Because of the special interest in the installed collector façade, there is a more detailed monitoring of the solar loop. Additionally to the sensors described above, there are temperature sensors installed for flow and return temperature for each of the three collector strings. Furthermore, flow and return temperature of a single collector as well as the temperature behind the façade are monitored. Figure 3 shows the monitoring concept of the solar loop.

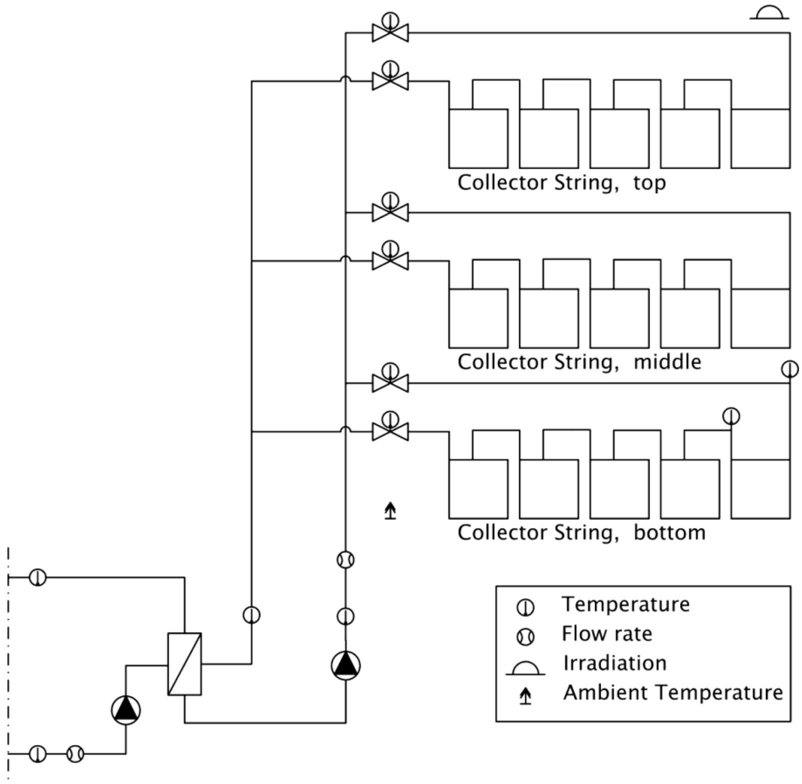


Fig. 3: Measuring concept of the solar loop. Beside the temperature sensors on primary and secondary side of the heat exchanger, there are also sensors installed in order to measure the flow and return temperatures of each collector string. Moreover, a single collector of the lower string is monitored as well as the temperature behind the facade.

4. Data processing and visualization feature

Data processing is realized with a database sever system developed at Kassel University, where measured data is transferred via email using a mobile communication network. The data files attached to the emails are parsed to a defined data structure before they are written into the database. Once stored in the database, data is in principle available from everywhere assumed a user has got access privileges. A more detailed description of the server concept can be found in (Kuethe, 2011). For manually monitoring, there is a visualization interface implemented, which can be used within common web browsers. Hence, no additional software needs to be installed in order to carry out a graphical data analysis of the monitored system. In the input form the user can choose sensors to be displayed for two y-axes and a custom date interval. Furthermore, in order to increase the performance, the data interval can be defined to show only every n^{th} value. Figure 4 shows a screenshot of the input form.

Newly generated graphs always open up in new tabs. Hence, several graphs can be displayed at the same time and it can be switched easily between one or more graphs for comparing or overlaying results. Moreover, there is the possibility to toggle sensors in order to hide and show curves. For detailed views, zoom functionality is also integrated and it can be switched to the previous or next date interval. Figure 5 shows a plot, where several curves are hidden.

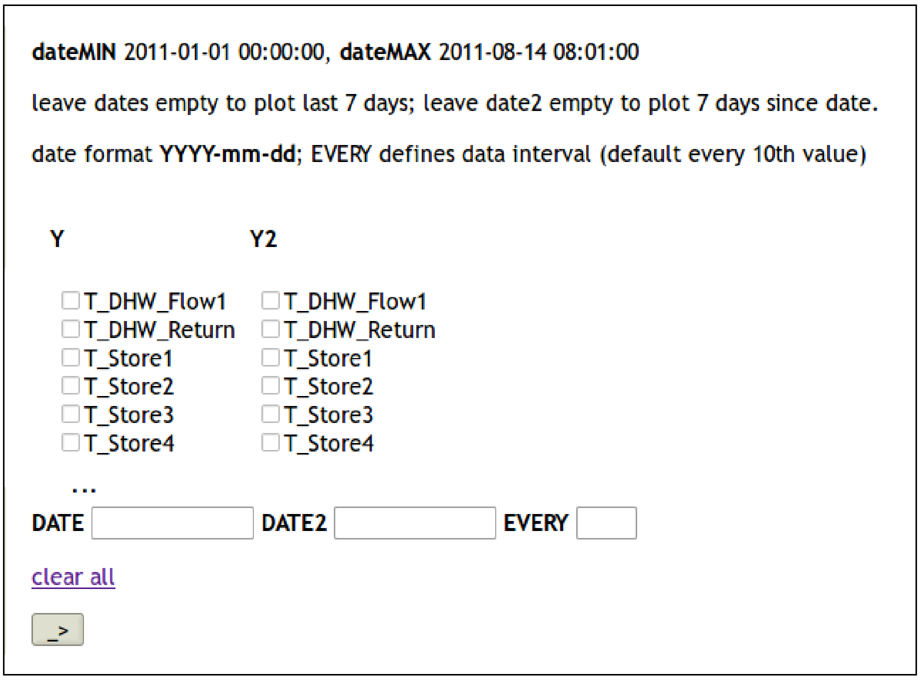


Fig. 4: Input form of the web interface of the visualization feature for a manual data analysis of monitored systems (Screenshot). The user can mark sensors to be displayed on primary and secondary y-axis. In the background the software establishes a connection to the database, where measured data is stored.

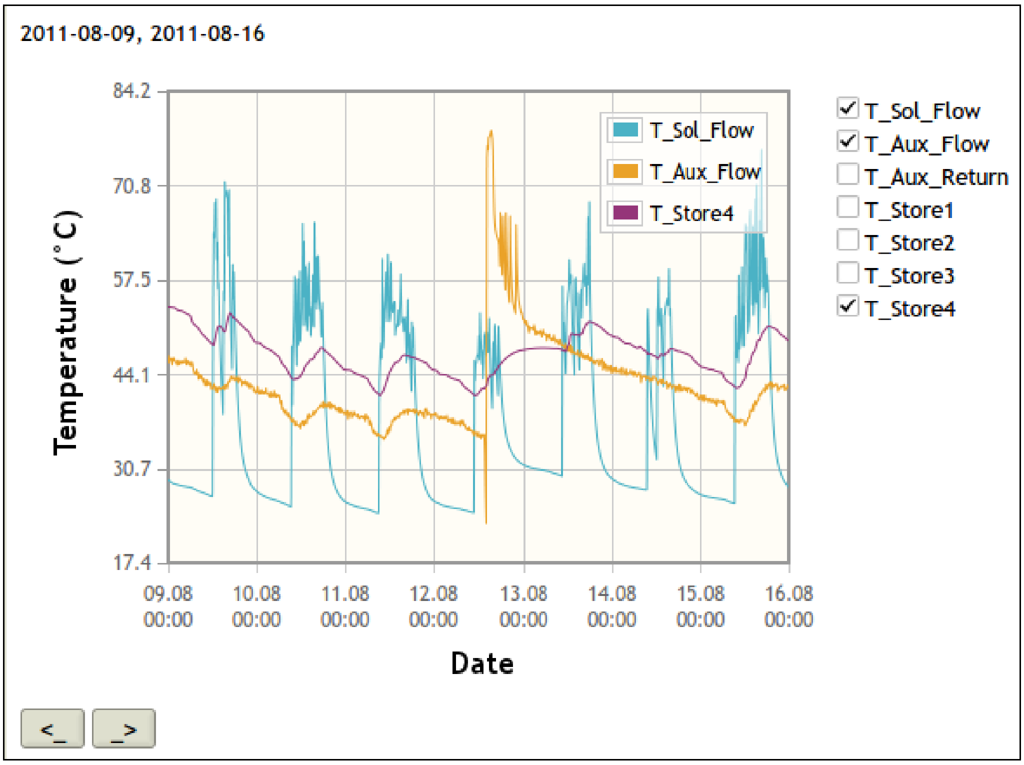


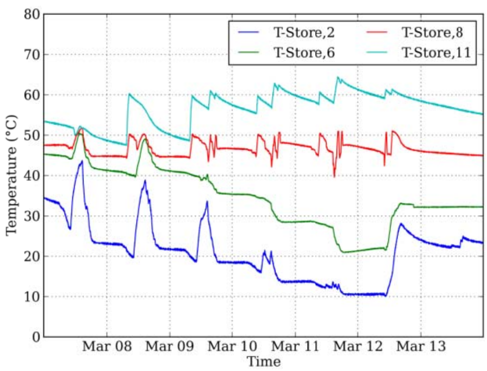
Fig. 5: Output of the web interface (Screenshot). Curves can be hidden or displayed by toggling sensors in the right checkbox. Graphs of the previous or next date interval can be generated by using the arrow buttons below the graph.

5. Data Analysis

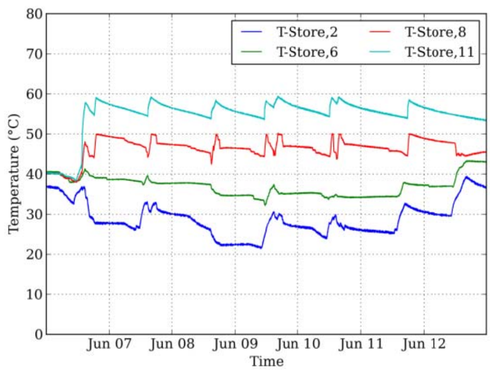
In this section some results of a carried out data analysis are presented. Thereby, the following aspects were examined:

- Stratification in the store
- Typical operating behavior of the system (charging and discharging of the store)
- Temperatures in the different strings of the collector façade, in a single collector and in the solar loop
- Solar energy yield for a sunny period with high irradiation in collector plane

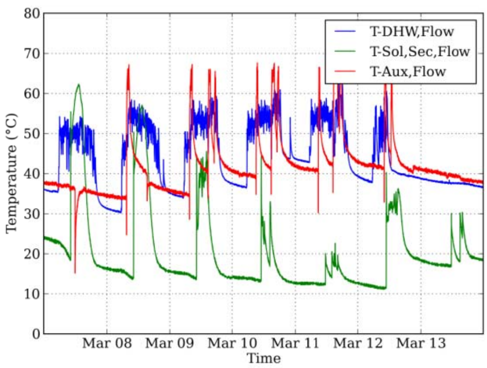
Figure 6 shows temperatures in different heights of the store and the charging and discharging of the store for one week in March (Fig. 6a+b) as well as for one week in June (Fig. 6c+d). As one can see the desired stratification works very well. In the upper part is a temperature between 60 and 55 °C while the layer below holds a temperature between 50 and 45°C and so on. Thereby, the upper part is heated by the installed back-up heater, while the lower part is charged by the collector façade (cf. also hydraulic scheme in Figure 2).



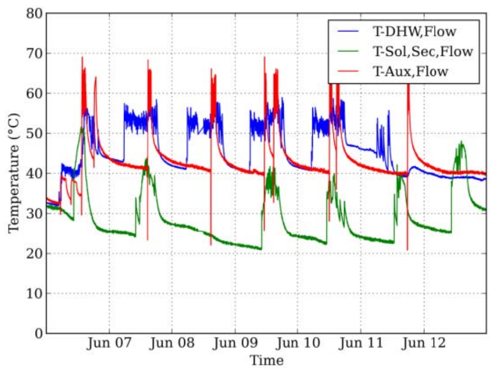
(a)



(c)



(b)

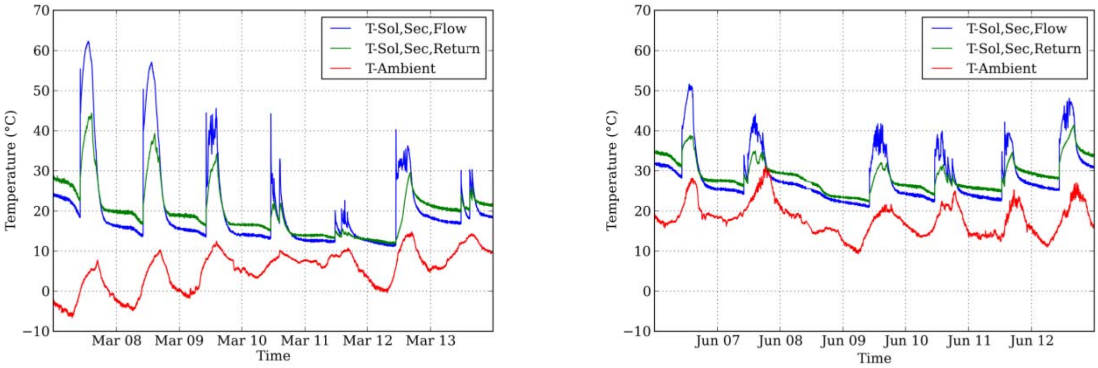


(d)

Fig. 6: Temperatures in the store and charging and discharging of the store for one week in March (a+b) and one week in June (c+d). It shows that stratification in the store works as required. The mixing in the beginning come about because there is no heat demand on Sundays and therefore, the back-up heater does not heat up the upper part of the store. Furthermore, it can be seen that the lower part is charged by the solar loop. Because of the high demand, the heater must be switched on, even when there is a high input by solar (cf. a+b).

Regarding the domestic hot water demand, there is usually a daily draw from 6am to 8pm at working days, while on Saturdays demand ends at about 2pm. On Sundays there is typically no draw at all (Fig. 6b+d). The demand at working days is about 1000 l/d and can be satisfied by an internal corrugated pipe heat exchanger. Because of the high demand on working days, the auxiliary heater needs to be switched on even when there is a good solar energy yield (cf. Figure 6a+b).

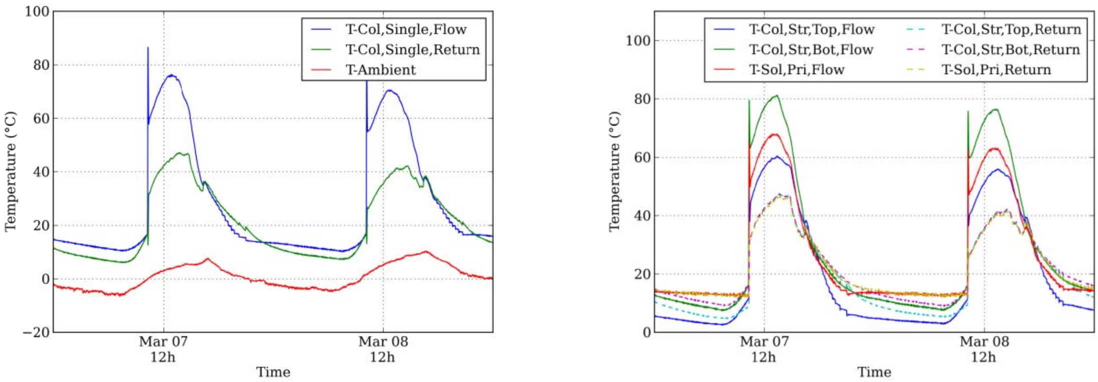
Figure 7 shows for the same periods the temperature on the secondary side of the solar loop as well as the ambient temperature. It can be seen that on a sunny day without clouds in March compared to June a higher temperature in the solar loop is reached. This is caused by a higher irradiation in collector plane in March. So, in March an irradiation up to 900W/m^2 was measured, while for the presented period in June the highest value was about 650W/m^2. The good performance of the solar loop in spring corresponds to a high heat demand in this period.



(a) (b)

Fig. 7: Temperatures on the secondary side of the solar loop and ambient temperature. As can be seen there are higher temperatures reached in the solar loop for sunny days in March than in June. This behavior is due to a higher irradiation in collector plane in March. For the shown week in March an irradiation up to 900 W/m^2 was measured, while for the period in June only about 650 W/m^2 were monitored.

In the next plots the temperature in a single collector as well as the temperatures in the different collector strings was examined. Figure 8a shows that temperatures only up to 75°C are reached on sunny days with an irradiation of about 900W/m^2 in collector plane. This can be explained due to the high demand compared to the small installed collector area. Furthermore, partial shading of the upper part of the collector façade causes or aggravates hydraulic effects like non-uniform flow in the different collector strings. As can be seen in Figure 8b the temperature in the upper string of the collector field is noticeable lower than in the lower one. This effect lowers the temperature in the solar loop and has to be examined more detailed.



(a) (b)

Fig. 8: (a) Flow and return temperature in a single collector. On sunny days with an irradiance of about 900 W/m^2 in collector plane temperatures only up to 75°C are reached due to a high demand compared to the small installed collector area. (b) Temperatures in the different strings (str) of the collector field and on the primary side of the solar loop. Due to shading on the upper string causing or aggravating hydraulic effects like non-uniform flow in the different strings temperatures are noticeable lower than in the lower string. This lowers the temperature in the solar loop.

Figure 9 shows flow and return temperature as well as temperature in the lower part of the store where solar charging takes place. A sunny period of two weeks with a high irradiance in collector plane (between 700 and 900 W/m^2) was chosen. For this period the solar energy yield is calculated with 364 kWh. This value can be significantly improved in a new installation avoiding shading effects (cf. also Heinzen, 2011) and non-uniform flow in the different collector strings as described above.

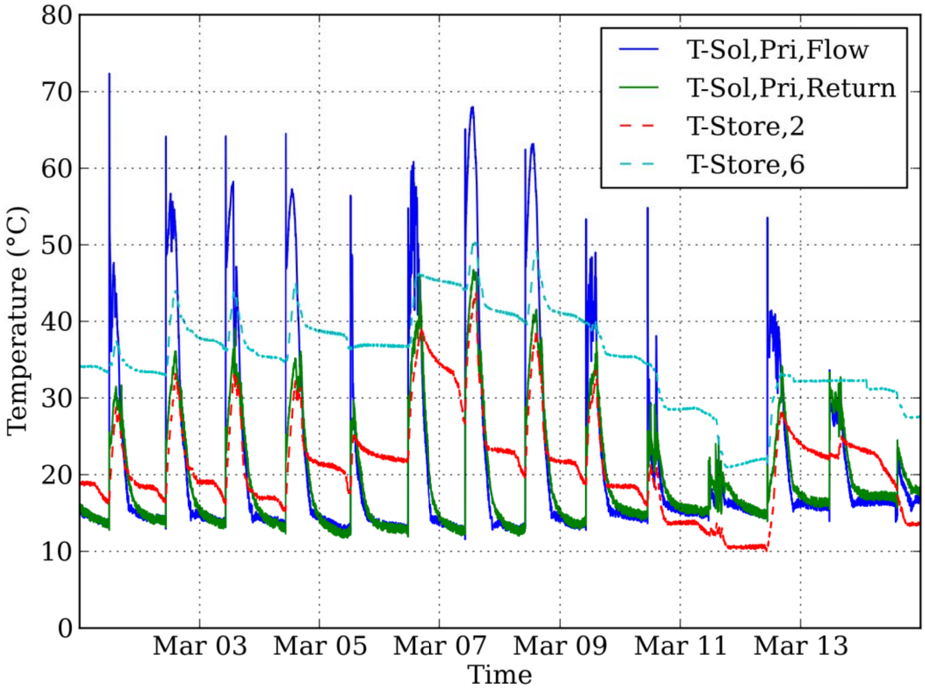


Fig. 9: Charging of the lower part of the store by the solar loop. For the shown sunny two week period with a high irradiation in collector plane a solar energy yield of 364 kWh is reached.

6. Summary and Outlook

The data analysis of the pilot plant of a solar thermal energy façade including heat insulation, heat production and architectural modernization presented in this paper showed that the operating behavior of the complete system is as required. Stratification in the store is very good. Because of a high hot water demand, the lower part of the store can usually always be charged by the solar loop when there is enough irradiation available. Due to the high demand compared to the small installed collector area temperatures of only 75°C are reached in a single collector on a sunny day with high irradiation in collector plane. A higher irradiation in collector plane in March (about 900 W/m^2) than in the summer month (only about 650 W/m^2 were measured on sunny days) leads to a much better solar energy yield for the period in spring time, where there is high room heating demand. Nevertheless different flow temperatures in the strings of the collector façade could be identified. This leads to losses in the solar loop, which are caused or aggravated by a partial shading of the façade of the pilot plant, which can be avoided in further installations. Moreover, larger collector areas should be installed respectively to the demand.

Beyond that, the pilot plant was implemented successfully and the system is excellently usable for renovation purposes; the product *SonnEn+ façade* can be delivered by the consortium leader STAHLBAU LAMPARTER.

7. Acknowledgements

This project (HA-Projekt-Nr.: 186/09-16) is supported by Hessen ModellProjekte funded by LOEWE - Landes-Offensive zur Entwicklung Wissenschaftlich-ökonomischer Exzellenz, Förderlinie 3: KMU-Verbundvorhaben.

8. References

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