USING THE SUMMER HEAT IN WINTER

At first glance, one would hardly believe that a simple water tank could be enough to bring heat from summer into winter. But in fact, a storage tank with a volume of 12 cubic meters or more is enough to supply an apartment with heat and hot water from solar collectors for the entire winter. Because such storage solutions have been relatively expensive up to now, scientists from the universities in Rapperswil and Lucerne have been searching for ways to make the technology more economical in two research projects. One approach is to reduce the volume of the storage tanks and thereby their costs through optimization.

The apartment building in Huttwil contains a hot water storage tank (red tank) with a capacity of 110 m³; it brings solar heat from summer into the winter months. Photo: Jenni Energietechnik AG

A technical report about the results of two research projects in the field of solar heating and heat storage, which are financially supported by the Swiss Federal Office of Energy. The report has been published on the site www.gebaeudetechnik-news.ch (August 2021).

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The apartment building in Huttwil, built in 2020, is covered with 160 m² of solar collectors. These provide enough space heating and hot water to supply the eight apartments all year round. Photo: Jenni Energietechnik AG

A pressing problem of future energy supply can be summed up in a single issue: The Winter Power Gap. Behind this buzzword is the question of how to secure the growing electricity demand of heat pumps in winter, when nuclear power plants are shut down and electric cars require additional power from the grid. Photovoltaics (PV) provide limited output during the winter months, even with further expansion. One approach to mitigating the problem is seasonal heat storage, which can capture energy generated by solar systems during the summer months and use it to provide heat and hot water during winter.

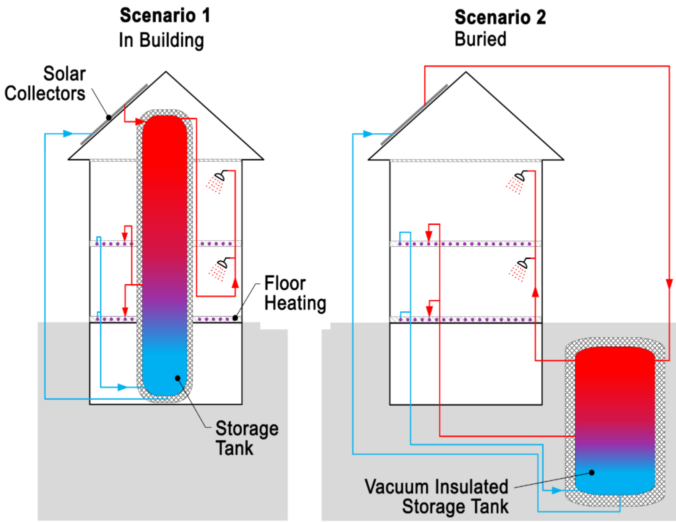
Heat Self-Sufficiency Has its Price

The potential of seasonal hot water storage systems was demonstrated by the Bernese solar pioneer Josef Jenni as early as 1989 with the construction of an energetically self-sufficient single-family home near Burgdorf (BE). In 2007 and 2015, Jenni Energietechnik AG built three residential buildings, each with eight apartments, at the same location: The first had 276 m² of collector area and a seasonal heat storage tank of 205 m³; the two later buildings achieved year-round spacing heating and hot-water supply thanks to optimization with significantly less collector area (160 m²) and a much smaller storage tank (110 m³). Another apartment building with the same solar storage system was built in Huttwil in 2020.

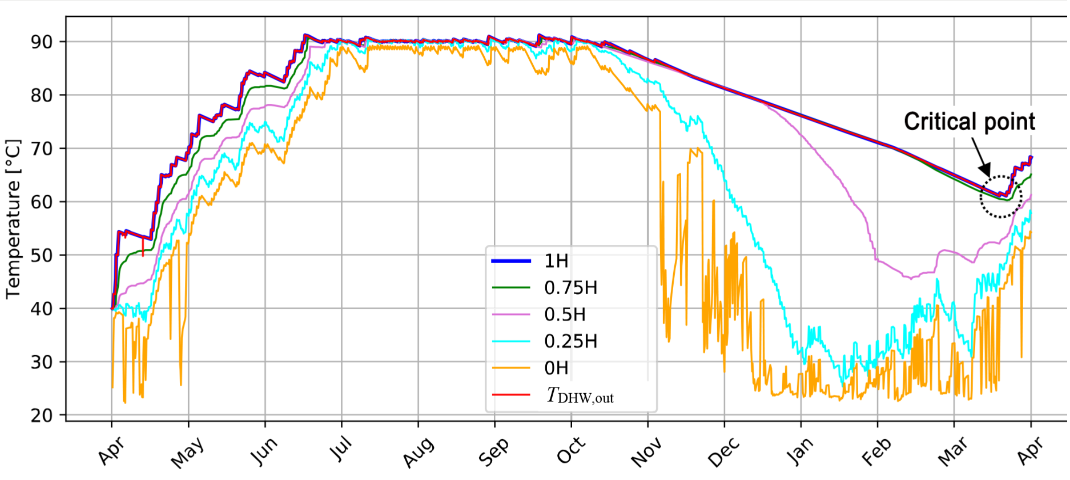
Despite the potential of this concept, only a handful of single- and multi-family homes in Switzerland use a seasonal storage system. The decisive factor is the cost, as Josef Timoteo Jenni, the son of the company founder Josef Jenni, says: "If you want to use a storage system to cover 100 percent of the heating demand throughout the year, rather than only 80 percent, for example, the costs of the energy system rise sharply. It's also a disadvantage that seasonal hot water storage systems usually count as living space; thereby reducing the usable living space and consequently cutting the rental income."

Two Improvements for More Efficiency

In this context, a team of researchers from the Lucerne University of Applied Sciences and Arts (HSLU) looked for potential ways to optimize seasonal hot water storage systems in the SFOE-funded project 'OPTSAIS.' The scientists of the Competence Center Thermal Energy Storage simulated an apartment building insulated according to Minergie standards with eight apartments and a roof covered with 190 m² of solar collectors. The seasonal hot water storage tank had a volume of 240 m³ in the reference scenario. It was dimensioned in such a way that it was able to completely satisfy the demand for space heating and provide domestic hot water at 60 degree Celsius throughout the year. "We set this boundary condition in order to avoid an additional heating system," says HSLU project manager Dr. Willy Villasmil and adds: "In principle, around one third of the buildings in Switzerland would be suitable for the installation of such a self-sufficient solar thermal system due to the orientation and size of the roof area as well as the climatic conditions."



Up to now, seasonal hot water storage tanks have usually been installed inside houses, because here the heat losses can be used for heating the house and no excavation costs are incurred. Illustration: Final report OPTSAIS

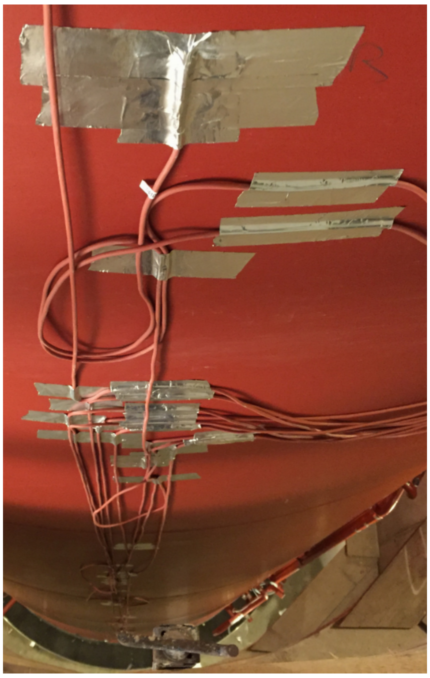


Typical temperature development during the year at different heights of the storage tank (0H is the temperature at the very bottom, 1H is the temperature at the very top; 0.25H, 0.5H and 0.75H are in between). TDHW represents the highest available temperature of domestic hot water. Graph: OPTSAIS Final Report

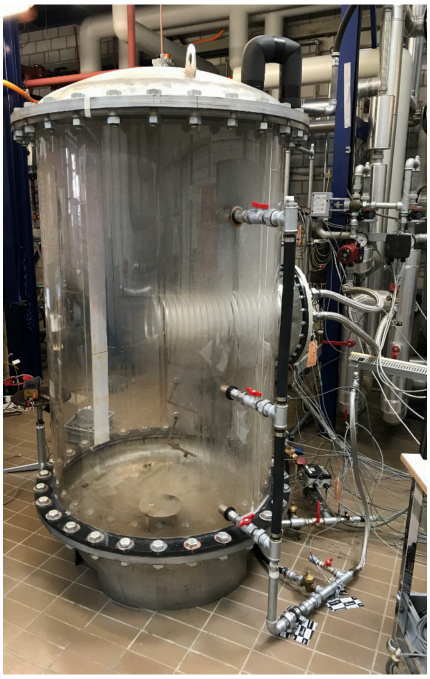
Villasmil and his team have identified two improvements to reduce the cost of such a solar system. The first is to reduce the flow rate (volumetric flow) in the solar collectors—which is high in conventional solar systems. When using a seasonal storage system, a low flow rate is advantageous, the research team notes in the OPTSAIS final report. With this control strategy, the collectors operate at a lower energy efficiency, but they deliver significantly higher temperatures. Thanks to the higher temperatures, the storage volume can be reduced by 30%, which brings significant cost benefits. By increasing the tilt angle of the solar collectors from 45 to 65 °, their efficiency can be increased - especially in the winter months when solar energy is scarce - and thus the storage volume can be reduced by a further 10 %.

Buried Storage Worth Testing

The second improvement for reducing costs is associated to the thermal insulation of the heat storage tank. If the insulation is not made with glass wool, as has been the case up to now, but with so-called vacuum insulation panels, the space requirement of the hot water tank can be reduced by 20%. In the case of an existing building equipped with a seasonal storage tank, cost savings of 10% can be achieved in this way. Nevertheless, Willy Villasmil sees this option with some



Sensors on a hot water tank to measure the water temperature of different layers. Photo: Interim report SensOpt



OPTSAIS researchers validated their simulation results on this 2m³ tank in the laboratory of the Lucerne School of Engineering & Architecture. Photo: OPTSAIS final report skepticism: “The vacuum insulation panels available today on the market were developed for room temperatures and not for high temperatures such as those found in this seasonal storage. Since installation is also more complex and the uncertainties greater, the bottom line is that there is only a limited advantage over glass wool.”

According to the researcher, one promising option is to bury the storage unit in the ground next to the house, instead of installing it inside the house. This would avoid undesirable effects on the habitable area. The HSLU researchers estimate the heat production costs of such a system at 60 Rp./kWh. If the storage tank is installed inside a new building, the costs are also around 60 Rp./kWh, and 1.20 Fr./kWh for an existing building.

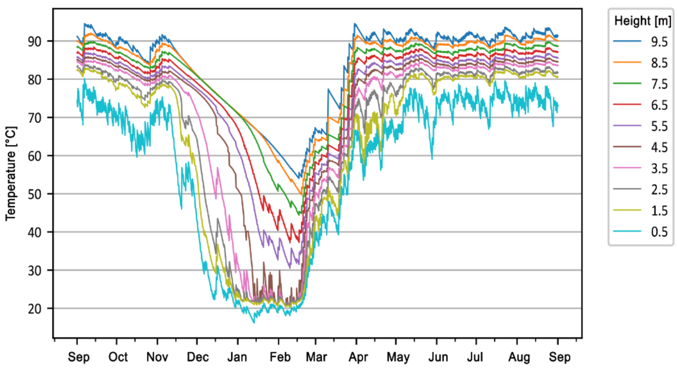
Mixed System with Photovoltaic and Heat Pump

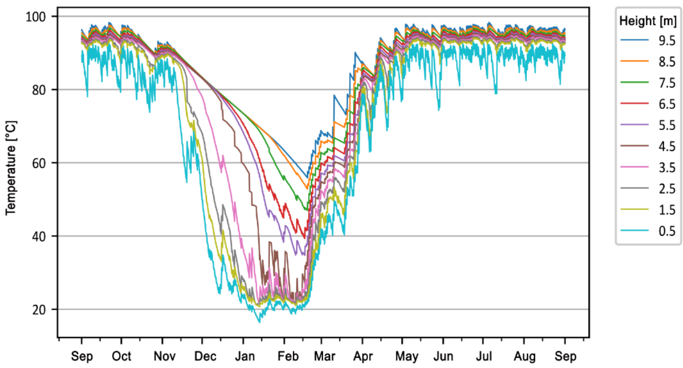
A different approach is being pursued by a team of researchers from the University of Applied Sciences of Eastern Switzerland (Fachhochschule Ostschweiz, OST) together with HSLU colleagues in the SensOpt project, which was also supported by the SFOE: here, the solar collector and hot water storage tank are combined with a photovoltaic (PV) system. The PV system supplies the electricity to operate a heat pump. “The two systems complement each other ideally, because the solar collectors provide heat at a high temperature, while the heat pump powered by solar power makes optimal use of the winter sun,” says OST project manager Florian Ruesch. The researchers based their calculations on a Jenni solar house (eight apartments; 160 m² collector area; heat storage with 110 m³), but replaced part of the collector area with PV modules in their simulations. The goal was to supply the house with solar heat and heat from the heat pump, which is operated solely with its own solar power, making the house completely self-sufficient in terms of heat and hot water.

Based on their simulations, an optimized energy system results with the following key values: The roof is outfitted with 50 m² of PV modules and 110 m² of solar collectors. A heat pump (10 kW) is recommended, which uses the foundation plate (appropriately piped) of the building as a heat source. The reason: the foundation plate provides higher source temperatures than the ambient air. According to OST calculations, the heat storage tank can be built 30% more compact (77 instead of 110 m³ volume) with this brine-water heat pump and a seasonally differentiated flow control of the solar

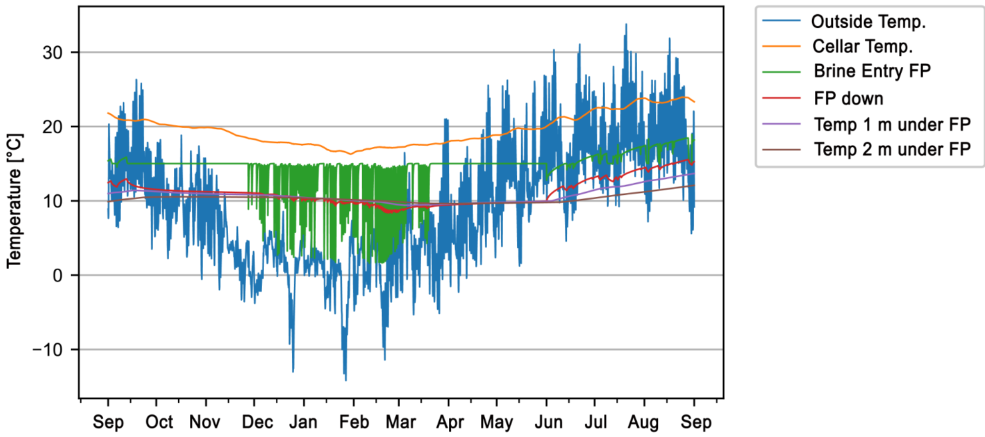
70 DEGREES OF DIFFERENCE

In principle, a water-based seasonal heat storage is nothing more than a standing water tank. The temperature can be 25 degrees Celsius at the bottom, while 95 degrees prevail at the top—so there is a temperature stratification, much like that experienced when swimming in a lake— although the temperature difference is less dramatic. If water is taken from the storage tank for space heating or production of domestic hot water, it is drawn from different heat zones and mixed to the desired temperature. The cooler water at the bottom of the storage tank is always used first. BV.





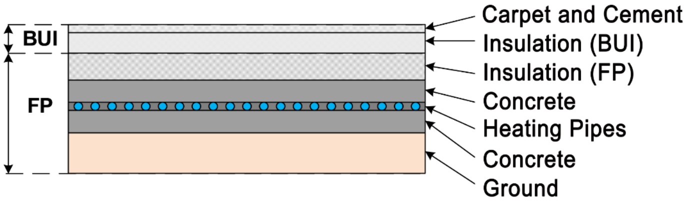
The figure on the left shows the year-round low-flow operation of the solar collectors (low flow rate, therefore higher temperatures): due to the low-flow operation, the temperature in the upper storage area rises again from mid-February. The figure on the right shows the combination of high-flow operation in summer and low-flow operation in winter: High-flow operation in summer charges the storage tank down to the lowest layer, so that temperatures of about 90°C are still reached in the entire storage tank even at the beginning of November. This allows the high temperatures to be maintained for a little longer. Graphics: SensOpt interim report



In winter, higher temperatures prevail in the foundation plate (red curve) than in the outside air (blue). Graphic: Interim report SensOpt

collectors. The smaller storage tank allows for more living space and thus higher rental income. Savings can also be made by using a shower water heat recovery system, which was only roughly considered in the project. Further financial benefits come from the fact that PV modules are cheaper than collectors and that PV generated electricity can be used in the building and fed into the grid.

"The mixed system of collectors, seasonal heat storage as well as heat pump, fed from the foundation plate, would be our recommendation for a future solar house," says Ruesch. "We estimate investment costs of about 200,000 Fr. for this system, but after that all the heat comes for free from the sun and there's even a small yield from the excess electricity from the PV system." The OST scientist and his colleagues have high hopes for this energy system. "100% solar-heated buildings are a sensible strategy against the winter electricity gap that we will soon be facing," Ruesch emphasizes. "The combination of solar thermal and photovoltaic/heat pump has great potential to make such systems cheaper and reduce space requirements."



Schematic representation of a foundation plate, which is equipped with piping during construction, through which the heat transfer fluid of the heat pump will later circulate. Illustration: Interim report SensOpt

- The **final report** on the research project 'Exergetic and Economic Optimization of Seasonal Thermal Energy Storage Systems' (OPTSAIS) can be found at: https://www.aramis.admin.ch/Texte/?ProjectID=40292

- The **final report** on the research project 'SensOpt - Sensitive Seasonal Thermal Energy Storage Optimally Used for Complete Solar Heating of Multi-Family Dwellings' is expected to be available by the end of 2021 at: https://www.aramis.admin.ch/Texte/?ProjectID=41677

- For **information** on the project, contact Dr. Elimar Frank (elimar.frank[at]frank-energy.com), head of the BFE research program Solar Heat and Heat Storage.

- Further **technical papers** on research, pilot, demonstration and flagship projects in the field of solar heating and heat storage can be found at www.bfe.admin.ch/ec-solar.

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