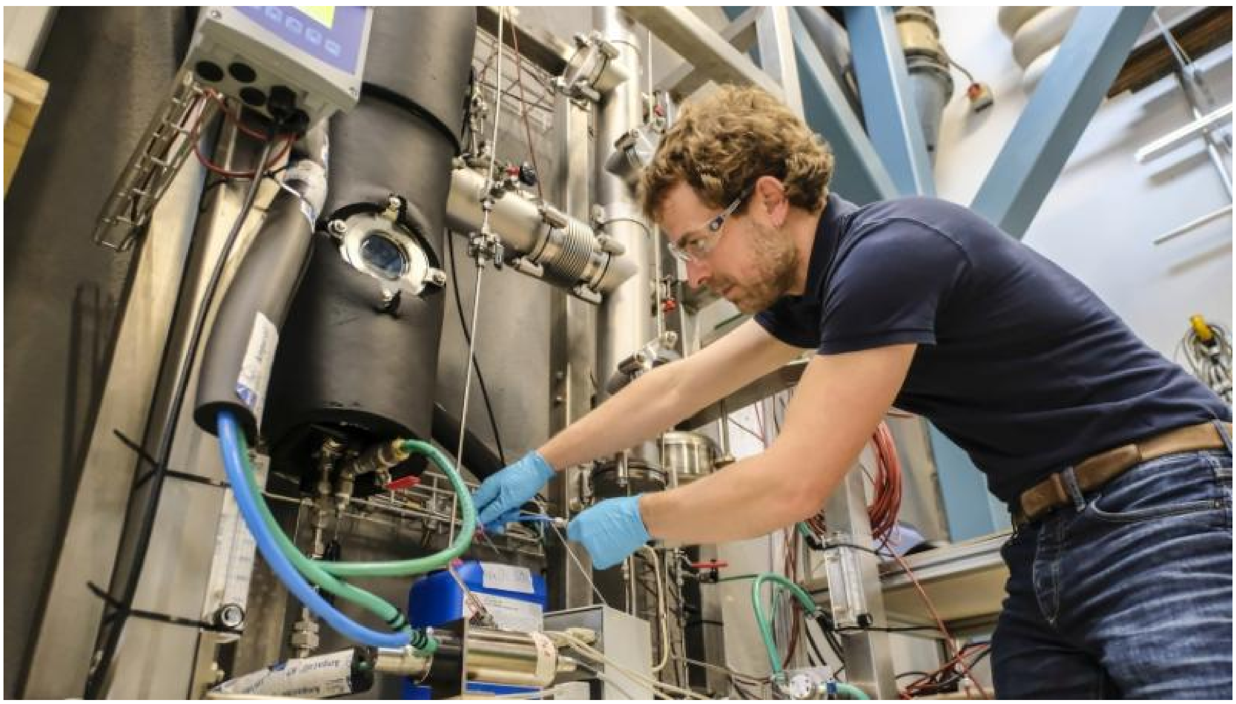
Storing thermal solar energy from summer to winter

January 11 2017, by Rainer Klose



Benjamin Fumey at his test facilty in the lab. The heat cycle has been working since fall of 2016. Credit: Swiss Federal Laboratories for Materials Science and Technology

Can thermal solar energy be stored until wintertime? Within a European research consortium Empa scientists and their colleagues have spent four years studying this question by pitting three different techniques against each other.

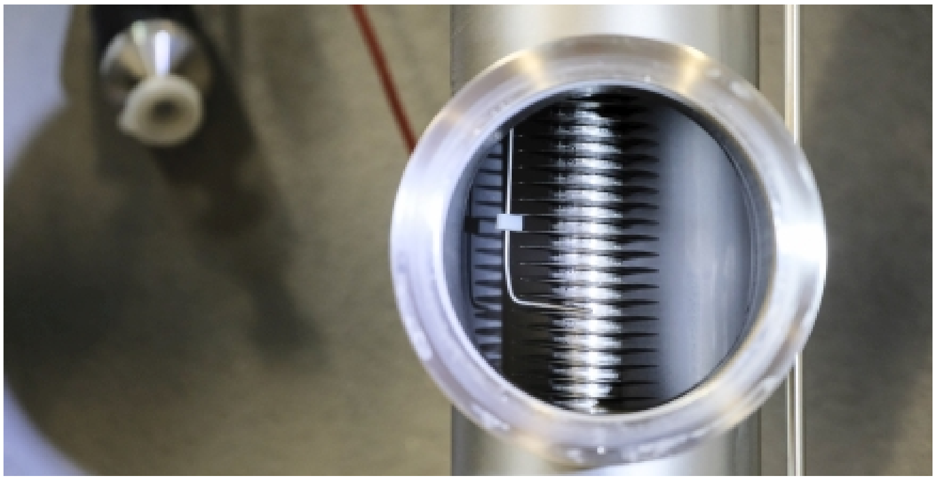
We are still a far cry from a sustainable energy supply: in 2014, 71 percent of all privately-owned apartments and houses in Switzerland were heated with fossil fuels, and 60 percent of the hot water consumed in private households is generated in this way. In other words, a considerable amount of fossil energy could be saved if we were able to store heat from sunny summer days until wintertime and retrieve it at the flick of a switch. Is there a way to do this? It certainly looks like it. Since autumn of 2016, following several years of research, Empa has a plant on a lab scale in operation that works reliably and is able to store heat in the long term. But the road to get there was long and winding.

The theory behind this kind of heat storage is fairly straightforward: if you pour water into a beaker containing solid or concentrated sodium hydroxide (NaOH), the mixture heats up. The dilution is exothermic: chemical energy is released in the form of heat. Moreover, sodium hydroxide solution is highly hygroscopic and able to absorb water vapor. The condensation heat obtained as a result warms up the sodium hydroxide solution even more.

Summer heat in a storage tank

The other way round is also possible: if we feed energy into a dilute sodium hydroxide solution in the form of heat, the water evaporates; the sodium hydroxide solution will get more concentrated and thus stores the supplied energy. This solution can be kept for months and even years, or transported in tanks. If it comes into contact with water (vapor) again, the stored heat is re-released.

So much for the theory, anyway. But could the beaker experiment be replicated on a scale capable of storing enough energy for a single-family household? Empa researchers Robert Weber and Benjamin Fumey rolled up their sleeves and got down to work. They used an insulated sea container as an experimental laboratory on Empa's campus in Dübendorf – a safety precaution as concentrated sodium hydroxide solution is highly corrosive. If the system were to spring a leak, it would be preferable for the aggressive liquid to slosh through the container instead of Empa's laboratory building.



Heat exchangers from instant water heaters provided the solution: the sodium hydroxide solution spirals along a pipe, absorbs water vapor and emits heat. Credit: Swiss Federal Laboratories for Materials Science and Technology

Unfortunately, the so-called COMTES prototype didn't work as anticipated. The researchers had opted for a falling film evaporator – a system used in the food industry to condense orange juice into a concentrate, for instance. Instead of flowing correctly around the heat exchanger, however, the thick sodium hydroxide solution formed large drops. It absorbed too little water vapor and the amount of heat that was transferred remained too low.

Then Fumey had a brainwave: the viscous storage medium should trickle along a pipe in a spiral, absorb water vapor on the way and transfer the generated heat to the pipe. The reverse – charging the medium – should also be possible using the same technique, only the other way round. It worked. And the best thing about it: spiral-shaped heat exchangers are already available ex stock – heat exchangers from flow water heaters.

Fumey then optimized the lab system further: which fluctuations in NaOH concentration are optimal for efficiency? Which temperatures should the inflowing and outflowing water have? Water vapor at a temperature of five to ten degrees is required to drain the store. This water vapor can be produced with heat from a geothermal probe, for instance. In the process, 50-percent sodium hydroxide solution runs down the outside of the spiral heat exchanger pipe and is thinned to 30 percent in the steam atmosphere. The water inside the pipe heats up to around 50 degrees Celsius – which makes it just the ticket for floor heating.

"Charged" sodium hydroxide

While replenishing the store, the 30-percent, "discharged" sodium hydroxide solution trickles downwards around the spiral pipe. Inside the pipe flows 60-degree hot water, which can be produced by a solar collector, for instance. The water from the sodium hydroxide solution evaporates; the water vapor is removed and condensed. The condensation heat is conducted into a geothermal probe, where it is stored. The sodium hydroxide solution that leaves the heat exchanger after charging is concentrated to 50 percent again, i.e. "charged" with thermal energy.

"This method enables solar energy to be stored in the form of chemical energy from the summer until the wintertime," says Fumey. "And that's not all: the stored heat can also be transported elsewhere in the form of concentrated sodium hydroxide solution, which makes it flexible to use." The search for industrial partners to help build a compact household system on the basis of the Empa lab model has now begun. The next prototype of the sodium hydroxide storage system could then be used in NEST, for example.

Provided by Swiss Federal Laboratories for Materials Science and Technology