An alternative to the Tesla Powerwall

Rechargeable batteries based on sodium chloride are not yet as common as lithium-ion batteries, but for selected purposes, they are already in use. A physicist from the Canton of Bern has now further developed the technology for home use: A salt-battery with 7 kWh storage capacity should enable owners of photovoltaic systems to provide their own solar electricity at night and in bad weather.

Dr. Cord-Henrich Dustmann with the salt battery-flat cell he developed. For homeowns with photovoltaic power systems, 126 flat cells of this type can be serially connected to create a battery that stores electricity. Photo: B. Vogel

Dr. Benedikt Vogel, commissioned by the Swiss Federal Office of Energy (SFOE)

Many operators of photovoltaic systems would like to use as much electricity as possible for their own purposes. For this they need batteries that store solar power for hours or days until it is needed. Electricity storage units with 2 to 10 kWh capacity for use in households are now on the market, usually in the form of lead or lithium-ion batteries. With prices ranging from 10000 to 15000 Fr., they are still quite expensive. In addition, lithium-ion batteries carry safety concerns – they can, for example, overheat and catch fire as occurred at the beginning of 2013 on a Boeing Dreamliner, which made headlines.

"With our salt battery project, we want to bring a battery on the market, which is not only cheaper than currently available batteries, but also safer than lithium-ion technology," says Dr. Cord-Henrich Dustmann. Dustmann studied physics in Berlin and Karlsruhe. Later at ABB Mannheim, for years he studied superconducting magnets and sodium-sulfur

A technical report about the results of a research project in the field of batteries and supercapacitors, which is financially supported by the Swiss Federal Office of Energy.

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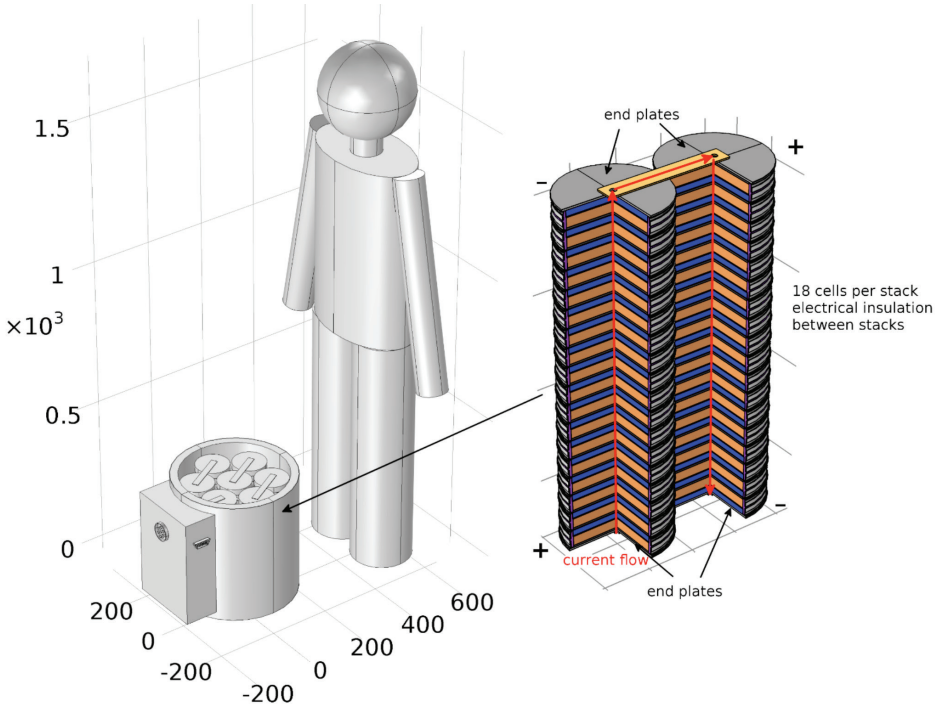
batteries and finally became involved with salt storage technology. Since 2011, the German battery expert has built on a former army site in Meiringen (BE), under the name Battery Consult GmbH, a development center for salt batteries. With nine young employees and financial support from the Swiss Federal Office of Energy, the 70 year-old scientist is further developing the battery-type – previously under the manufacturer's name ZEBRA, SoNick or Durathon for the emergency backup power for mobile base stations, as a power storage unit for use in electric buses and also in rescue submarines made by Rolls-Royce (Submarine Rescue Vehicle).

Proof of concept of a flat cell

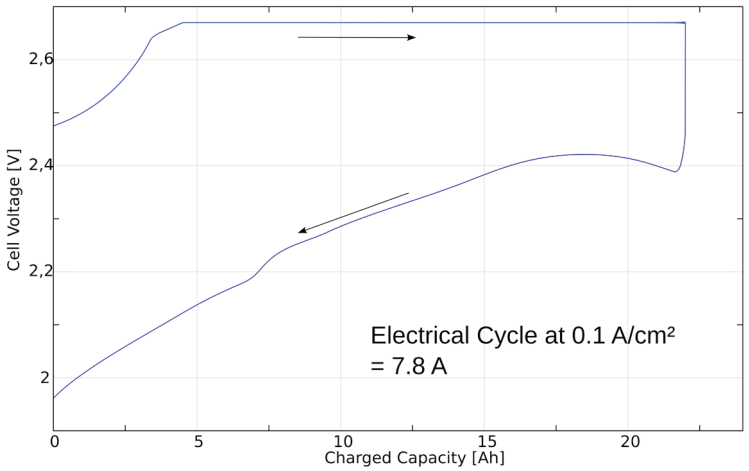
Cord-Henrich Dustmann sits at the conference table and shows visitors a cylindrical object with a diameter of about 30 mm. It is a salt battery in the form of a flat cell. "Many have tried before us to build such a flat cell, but none of these projects has made it to market," says Dustmann. So far, salt cells are built exclusively in tubular form. Flat cells use the same operating principle, but thanks to their innovative design, can be made at lower cost. With the small cylinder that the director of Battery Consult GmbH holds between his fingers, proof of concept has been acheived: the flat cell operates with a power output of 2.58 V and can store 1.5 Ah of electricity.

This flat cell works, but only on a small scale. During the next phase, the development team therefore wants to enlarge the cell from 30 to 100 mm in diameter and to a storage capacity of 23 Ah. Eighteen of these cells will then be stacked and seven of these stacks will then be bound into a battery: A total of 126 serially-connected salt battery cells would then at a power output of 325V, be able to store a total of 7 kWh of electric energy.

"This battery storage unit would be ideally suited to a PV system with, for example, 7 kWp and annual yield of 5000-7000 kWh, which is typical for a single family home," says Dustmann, "with this operators can achieve a day-night balance and the power output of 325 Volts allows a cost-effective connection to the power grid. With this battery, PV producers could increase their self-sufficiency rate by 30 to 70%."



Concept of a salt battery for commercial use: Seven stacks each with 18 flat cells are combined to form a battery module, which has a storage capacity of 7 kWh. Illustration: Battery Consult



Charge-discharge curve of a flat cell-salt battery with a capacity of 23 Ah: Charging is carried out at a higher voltage than cell discharge. Graphics: Battery Consult

Cord-Henrich Dustmann's vision sounds convincing - why is it not already reality? The beginnings of the technology reach back to the 1980s, when the first sodium-sulfur battery emerged, followed later by the salt battery with saline as a positive electrode. In Dustmann's opinion, during the 1990's interest in lithium technology rivaled interest in salt batteries because Sony needed lithium-ion batteries for their video cameras. Because of this application, lithium-battery technology was vigorously developed and consequently the batteries have widespread applications today. The developers of the salt battery (then: ZEBRA battery) did not however benefit from such a demand. They put them to use in electric vehicles, but at the time, there was no pressing need. But the time has now come for the salt battery, Dustmann is convinced - as storage for renewable solar power.

Need for decentralized storage

A salt battery consists of two electrodes and electrolyte in between. The materials are chosen such that they allow for the chemical storage of electricity (see box). To build a salt battery, one requires two salts (sodium chloride and aluminum chloride), metal (iron and/or nickel) as well as the raw material for the ceramic-containing electrolyte (aluminum oxide). All of these raw materials are available around the globe in many places and in large quantities. The materials are relatively cheap and are recyclable at the end of the battery's lifetime. Today salt batteries are a bit more expensive than lithium-ion batteries produced in large quantities. Battery developer Dustmann is convinced that the price per kWh of storage capacity will drop to 500 francs – thanks to lower production costs for the flat-cell design, but also thanks to a more less expensive sealant. For the 7 kWh battery, the production costs float around 3500 Fr.

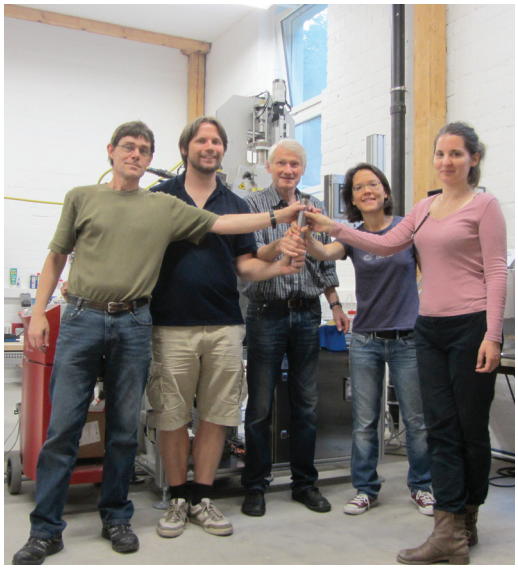
Competing with Tesla

This 3500 Fr., which the battery pioneer from Meiringen throws into the room, sounds like the challenge of David versus Goliath. The 3500 Fr. cost is only slightly more than the expected USD 3000 cost of the lithium-ion battery developed in summer 2015 by the Californian battery manufactuerer Tesla, with which the company aims to conquer the market for decentralized electricity storage. Company CEO Elon Musk announced the USD 3000 price for the 7 kWh version of the battery, called "Powerwall," this past spring. Next year a USD 5 billion manufacturing facility is expected to go into operation the US state of Nevada, which will supply the competetively priced batteries.

The battery pioneer from Meiringen nevertheless believes in the potential of a salt battery. "We want to be the alternative for those people who are willing to pay a little more for secure battery storage," he says, alluding to the observed risk of lithium-ion batteries catching fire. In three years, he wants to have the alternative battery on the market. Until then,

his research team must succeeed in upscaling the present prototype flat cells to be 14 times more powerful. If a prototype of a powerful decentralized electricity storage battery is achieved, the construction of a production plant will follow. Currently Dustmann is negotiating with investors who share his vision of a rapidly growing market for the storage of renewable energy. Competitors who are working on the same battery technology include industrial heavyweights such as the Italian FIAMM group or the American company General Electric.

- For further information on the project, please contact Martin Pulfer, head of the BFE-research program batteries and supercapacitors: martin.pulfer[at]bfe.admin.ch
- For more information on the salt battery: www.batteryconsult.ch
- For more technical papers on research, pilot, demonstration and flagship projects in the field of batteries and supercapacitors: www.bfe.admin.ch/CT/strom

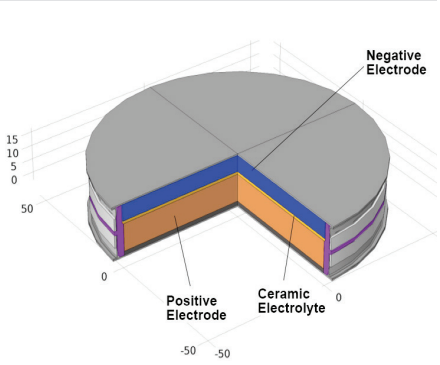


The Battery Consult GmbH team. In the middle: Dr. Cord-Henrich Dustmann. Photo: Alex Leuthold

How a salt battery works

Rechargeable batteries (accumulators) have evolved rapidly in recent decades: After the lead battery, came nickel-cadmium batteries and the nickel-metal hydride battery. In the1990s, the lithium-ion battery embarked on its triump, which today is widely used in cell phones, laptops or electric cars. Its name derives from the fact that its negative electrode consists of carbon embedded in lithium and that lithium-ions are exchanged between electrodes during charging and discharging, thus forming the basis for the storage of chemical energy. In the salt battery discharge of lithium ions is replaced by sodium ions. Since the sodium in the positive electrode is bound to chlorine to form sodium chloride (NaCl, known as common salt), the sodium-ion battery is also referred to as a salt battery. Like other forms of chemical battery storage, the salt battery consists of two metallic (and thus good electrical conducters) electrodes separated only by an ion-conducting electrolyte.

In the case of Battery Consult's flat cell, the positive electrode (orange) consists of salt (NaCl) and a metal such as iron (Fe) and/or nickel (Ni). The negative electrode (blue) consists of sodium (Na). The two electrodes are separated by an electrolyte consisting of a beta-ceramic (a crystal structure of aluminum oxide/Al_2O_3); this fabric is conductive for (positively charged) sodium ions, but not to (negatively charged) electrons. Graphic: Battery Consult



This chemical setup is ideal for electricity storage: If a voltage is applied to the two electrodes of the flat cell, the sodium chloride bond breaks at the the positive electrode (orange), forming sodium ions (positively charged particles), that are drawn through the electrolyte towards the negative electrode (blue), where they bind electrons from the current and are thereby reduced to sodium. When this chemical reaction is complete, the battery is charged. The chemical compound at the positive electrode is now at a higher energy level. Since the two poles of the battery are connected via a circuit - the opposite reaction will follow: The sodium ions migrate from the negative to positive electrode, at the same time the battery discharges through the electric circuit: the battery supplies electricity.

There remains a key element of the salt battery: In order for the positive electrode to provide the necessary conductivity, an additional substance (sodium aluminum chloride/$NaAlCl_4$) must be present. This salt secures the required conductivity for sodium ions, however, only if it is melted. This is also the reason why salt batteries must be operated at high temperatures, such as in the case of the flat cell battery from Battery Consult which must be operated at 250 °C. To start the chemical reaction, the necessary heat must first be supplied from the outside. During the process, the required heat comes from the chemical reaction itself. Salt batteries can be switched off by simple cooling, which improves their safety. BV

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09/2015