

# Battery Storage with All Its Different Facets



Electricity production from photovoltaic and wind power plants fluctuates. If we want to make more use of it, we need to be able to store surplus electricity and then make it available when needed.

Birgit Baustädter



**In addition to large energy storage systems, batteries in electric cars and in households are also becoming bigger and more robust. At TU Graz, researchers are looking deep inside materials, improving safety and performance and taking a closer look at material cycles.**

**B**atteries accompany us everywhere in our everyday lives. As circular, cylindrical or flat cells in all kinds of household appliances, and invisibly installed in our mobile phones or as energy storage in electrically powered vehicles. They are also becoming increasingly important as storage facilities for electricity from renewable energy sources such as wind and solar power. Unlike oil, gas and coal, electricity production from these renewable energy sources fluctuates naturally. This volatility is mainly due to weather conditions, but also to the seasons, and has to be balanced out. This is an important issue, especially with regard to grid stability (see also Robert Schürhuber's commentary on page 8). Surplus electricity can be transported abroad in some cases, but as the expansion of renewable energy sources is being stepped up across Europe, the question of how to store electricity temporarily is also becoming increasingly important in our neighbouring countries. In addition, exporting surplus electricity does not solve the problem of a lack of production on windless or cloudy days, for which stored energy must also be provided.

Due to the geographical conditions in Austria, energy is primarily stored temporarily in pumped-storage power plants to generate electricity. During slack periods, they can convert this energy stored in reservoirs into electrical energy by converting it in water turbines and generators and feeding it into the grid. In future, however, storage requirements will also be covered by large batteries, as is already being implemented in other countries. Robert Schürhuber from the Institute of Electrical Power Systems explains the challenge involved:

***“Electricity storage systems must be cheap, large and fast. However, it's very difficult to reconcile these aspects.”***

To solve this problem, scientists at TU Graz are conducting intensive research into both improvements and completely new battery concepts. And, of course, into safety, for which the requirements are becoming ever more stringent with greater distribution and higher storage capacities.

## MATERIALS FOR BATTERIES

The materials used for batteries are a decisive factor in making them more environmentally friendly and more powerful. Basically, a battery consists of an anode and a cathode, with an electrolyte in between in which the ions move from one battery pole to the other during charging and discharging. Batteries are made from various materials such as cobalt or lithium, which are harmful to the environment when they are mined or disposed of in landfills. Researchers are therefore investigating which new and less environmentally harmful materials are available that might make batteries even more powerful.

The Institute of Chemistry and Technology of Materials is one of the organisations involved. A wide variety of energy materials are analysed, improved and newly developed here using the latest spectroscopic tools and synthesis methods. The researchers are particularly interested in different reactions in the materials, kinetic phenomena and dynamic processes. The research results are then used in applications such as energy storage and solar plants.

At the institute, Bernhard Gadermaier investigates, for example, how ions move in solids and how this movement is related to the atomic arrangement in the solid. “On the one hand, I'm doing this out of basic interest, because I'm simply interested in how this movement takes place. On the other hand, it is of course also important to know about its application and perhaps to be able to control and utilise the movement of the ions.” The ultimate aim is to use research to extend the life of batteries, increase their energy density and improve their performance. “I often work on oxides that contain lithium, sodium or potassium. Recently, however, they have also been working intensively on mixed-ion conductors, which not only conduct ions – i.e. positively charged particles – but also negatively charged electrons. It's a very exciting dynamic.” He sees the transition from liquid to solid electrolytes in lithium-ion batteries as the current trend in materials, but also the shift towards sodium-ion technologies.



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Bernhard Gadermaier

VanillaFlow: TU Graz researcher Stefan Spirk and his project team have taken a completely new conceptual approach in recent years. With the help of AI, he conducted research into the use of vanillin as an environmentally friendly electrolyte for redox flow batteries. After successful preliminary work, the start-up Ecolyte emerged from the research. At the same time, the scientists received funding from the European Innovation Council (EIC) for their VanillaFlow 2023 project, which will accelerate its implementation in commercial products.

The Institute of Electron Microscopy and Nanoanalysis at TU Graz, which is involved in many of these projects, is looking deep into the interior of materials. Here, researchers use state-of-the-art microscopic and spectroscopic methods to analyse lithium iron phosphate, for example – one of the most important materials for batteries in electric cars. Last year, they were able to observe why batteries made from this material undercut their theoretical electricity storage capacities by as much as 25 per cent in some cases. Using transmission electron microscopes, they were able to systematically track the lithium ions as they travelled through the battery material, map their arrangement in the crystal lattice of an iron phosphate cathode with unprecedented resolution and precisely quantify their distribution in the crystal. “By combining different examination methods, we were able to determine where the lithium is positioned in the crystal channels and how it gets there,” explains Nikola Šimić, researcher at the institute. “The methods we have developed and the knowledge we have gained about ion diffusion can be transferred to other battery materials with only minor adjustments in order to characterise them even more precisely and refine them.”

The materials in batteries are also being analysed at the Institute of Materials Physics. In particular, the aim is to gain insights into the charging and discharging processes in lithium and sodium-ion batteries using magnetic measurement methods. This makes use of the fact that the typical cathode of such a battery consists of a transition metal oxide that is oxidised or reduced during charging and discharging. These electrochemical processes can be sensitively monitored using a so-called magnetometer in a specially developed measuring set-up.

Battery casing made of thin steel and wood.



M. Wagner – TU Graz



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Florian Feist

REGROWING  
COVER

## EMBEDDED IN WOOD

In addition to the battery itself, its housing can also be made more environmentally friendly. Currently it is often made of aluminium, but in the future it could consist of a thin steel shell in combination with wood. Wood has the advantage of consisting of tiny cells that collapse under high pressure and can therefore absorb a lot of energy in the event of a crash. “We use cork as fire protection, which carbonises at high temperatures. This greatly reduces its thermal conductivity.” This protects adjacent batteries – or, conversely, the vehicle interior and occupants. The enclosures performed excellently in safety experiments and simulations, and even better than the market standard in fire protection tests.

*“We were surprised ourselves at how well our system works”*

says a delighted Feist. In the next step, the researcher wants to test whether low-grade wood and old cork can also be used, – something which could improve the environmental impact by another step.

## SAFE ENERGY STORAGE

The aforementioned safety is one of the most important factors in the future use of batteries. If energy storage systems are to be more powerful and charged more quickly, then the safety concepts must grow to the same extent.

The recently founded FFG Comet Centre Battery4Life is leading the way in this area, with the aim of making batteries and energy storage systems like lithium-ion batteries, safer, more powerful and better usable in the long term. For example, the behaviour of energy storage systems under high loads is being researched and analysed, prediction models are being built also using AI approaches and a close look is being taken at the ageing of batteries and, above all, how behavioural changes during the batteries lifetime affects safety during operation. Continuous monitoring of the batteries is also central to safe long-term operation in the first and second life; new measurement procedures and qualification methods are to be developed at the research centre for this purpose, among other things.

Intensive and dangerous tests are carried out at the Battery Safety Centre, which is located at the Vehicle Safety Institute. Here, batteries are compressed, squeezed, crushed and driven against the wall at extremely high speeds. The energy storage systems are tested until they fail, and valuable data is collected on their behaviour from classic operation to extreme situations. This data helps to define the load capacity limits of batteries, to reliably assess their safety after different loads, and subsequently to make statements about a possible second life, for example as stationary energy storage.

Next year, a new test bench will be added to the centre, which will provide new research findings, particularly in the area of mechanical stress and battery characterisation. For example, researchers specifically subject batteries to pressure in order to simulate the condition of battery packs in an electric car.



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PERMANENT &  
LONG-TERM  
USABLE**

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Jörg Moser

The batteries in the pressure test can then be charged and discharged in order to determine electrical parameters. “But we can carry out more tests. Thanks to a sophisticated measuring system and the new test bench design, we will achieve a very high measurement accuracy that will exceed that of our current test benches many times over. This allows us to generate even more precise data for our simulation models,” says Jörg Moser, who heads the centre. The centre is open to collaborations and contract research from business and industry. Interested companies can submit research questions and the researchers at the centre develop the appropriate research design together with the client in order to investigate all relevant questions.

### MATERIAL CYCLES AND AUTOMATED RECYCLING

In addition to safety, the production and recycling of batteries is also an important topic at TU Graz. Together with AVL, the Institute of Production Engineering operates the Battery Innovation Centre on a large scale at the AVL site and on a smaller scale on the premises of TU Graz. Here, researchers are working on automated concepts for construction and quality control. A brand new addition to the Battbox project is the topic of recycling and material cycles. In addition to inspection and construction, the system will also be able to analyse, sort and, if necessary, dismantle battery packs in the future. The individual parts are then recycled or the valuable components and raw materials used to build new cells and storage systems.

To the Battery Safety  
Centre at TU Graz



### SUBSTITUTION CELL

The safety precautions at research facilities such as the Battery Safety Centre are of course extensive, as batteries are tested to their limits there. But there are also research projects in which batteries are an issue, but not so central that elaborate safety precautions such as those in the Battery Safety Centre have to be built.

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Roland Lorbeck



In order for cooling systems to work, for example, the heat development in a battery cell or battery pack has to be taken into account. The Institute of Thermodynamics and Sustainable Propulsion Systems is carrying out research on a substitution cell for precisely such cases. “It’s a classic flat cell, but inside, it only consists of a heating foil and electronics,” explains Eberhard Schutting, who is in charge of the project. “This allows us to simulate the heat development, but eliminates the sources of danger that can lead to a chemical reaction and fire in the event of borderline loads.” The surface of the substitution cell heats up like a conventional battery. Coupled with a sophisticated simulation that runs in the background on the test bench, operation can be modelled exactly.

Automated construction, inspection,  
analysis and dismantling of batteries.



### WHAT THE FUTURE HAS IN STORE

The topic of energy storage will continue to occupy us extensively in the future. Whether in the field of batteries, their continued development and improvement or in alternative storage systems such as fuel cells or similar systems.

**The main focus of research at TU Graz is on new materials that make batteries more powerful and more environmentally friendly**

but also on the safety of batteries and the demands that increasing storage capacities will pose in this area in the future.