energy innovation austria

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Current developments and examples of sustainable energy technologies

Storage technologies for a sustainable energy system

As the share of fluctuating, decentral supplies of energy such as wind and solar power increases, major new challenges to our energy system present themselves. Pioneering technologies for storing electricity and heat may well play a key part in the sustainable, secure energy supply system of the future. In Austria research into a number of new approaches and strategies for storing electricity and heat from renewable sources of energy is currently in progress, including demonstration projects to test them under real-life conditions.

Model of active heat storage system SandTES
Photo: Vienna University of Technology, Institute for Energy Systems and Thermodynamics

Energy storage
Key technologies for the energy policy turnaround

Upper and lower basin of Limberg II pumped storage plant, Austria, Photo: Voith press image

Climate change, and the fact that we shall run out of fossil sources of energy, make it necessary to rethink our energy supply systems completely. It will be essential to increase the share of the energy mix contributed by renewables. The main technical challenge here is to harmonize the supply of energy from fluctuating sources with consumer demand, so as to ensure that electricity and heat are provided cost-effectively and in line with actual consumption. With suitable storage facilities energy generation and consumption can be uncoupled from each other timewise; so such facilities can play a central part in the energy system of the future.

Smart Grid and Storage facilities

As part of Smart Grids, storage facilities can help to ensure a reliable energy supply even if an increasing share of fluctuating sources of energy is integrated into grids. Via the strategic process Smart Grid 2.0 the Federal Ministry for Transport, Innovation and Technology (bmvit) is actively supporting this development in collaboration with the stakeholders from the energy sector, industry and research. The aim is to jointly evaluate the results obtained so far from research and demonstration, and to derive medium-term strategies and concrete plans of action for Austria from these.

Energy generation and consumption can be harmonized in grids by means of options for rescheduling loads and/or changing the rate of supply from generation facilities in response to an external signal (so-called “flexibilities”). Flexibility options including tying in energy storage devices – such as classical pumped-storage power stations or power-to-gas facilities. Batteries in electric-powered vehicles can also serve as storage devices, and help to reschedule loads if they are charged appropriately. The system can also be made more flexible overall by means of active distribution grids (e.g. with controllable substations). Linking the sectors electricity, heat and natural gas together in hybrid networks and systems has considerable potential. Utilizing power-to-heat or power-to-gas technologies can turn heat or natural-gas storage facilities into functional energy storage, making the energy system much more flexible than would be possible purely with electrical load rescheduling.

Economic evaluation

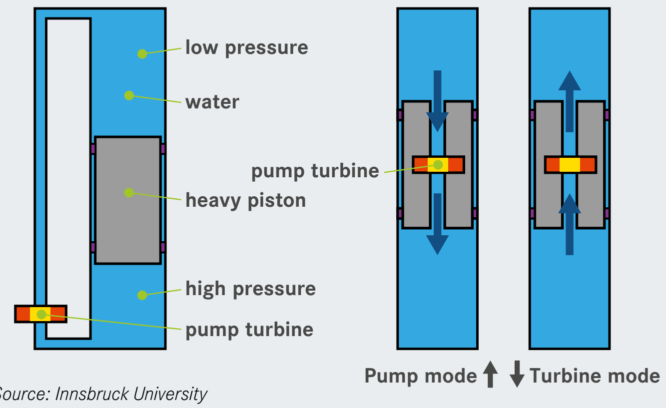
With the study “Stromspeicher 2050” by Vienna University of Technology on behalf of the Climate & Energy Fund, a first-ever analysis was performed of how the demand for electricity storage will develop in the Austrian and German electricity system up to 2030 and 2050 as the share of renewables in power generation increases. A number of scenarios were simulated, leading to a reduction in carbon-dioxide emissions of 76 % to 90 % for the sectors power generation, space heating, hot water and car traffic. With the aid of HiREPS, a simulation model with hourly resolution developed by the Energy Economics Group at Vienna University of Technology, the technical feasibility of a large proportion of electricity from renewables and the cost-effectiveness of flexibility options have been successfully simulated. The simulations show that expanding storage facilities, plus power-to-heat and managed charging for electric cars, can contribute to integrating a large proportion of electricity from renewables cost-effectively.

Research topics in the field of energy storage range from developing new materials to experimenting with entirely new storage approaches for fixed and mobile applications. Following we present various new research projects carried out within the funding programmes of bmvit and Climate & Energy Fund. ◘

Various technologies are used to store electricity and heat:

- Mechanical devices (flywheel, pumped-storage power station, compressed-air storage facility)
- Chemical systems (accumulators, lithium-ion battery or redox-flow battery, hydrogen)
- Electrical storage systems (capacitor, superconducting magnetic energy storage)
- Thermal storage systems (latent, sensible or thermo-chemical heat storage)

The Powertower principle



Source: Innsbruck University

Powertower small-scale test, Photo: Innsbruck University

Powertower
Large-scale hydraulic storage facility to store electricity locally

At Innsbruck University a pioneering system to store electricity locally is currently being developed and demonstrated in the hydraulic engineering field. The Powertower is a hydraulic energy storage facility based on the established technology of pumped-storage power stations, and operating at a similar level of efficiency. To store energy the facility generates potential energy; however, in contrast to pumped storage a difference in altitude is unnecessary. The system is flexible and can be employed independently of terrain; it is easy to integrate in new local energy supply structures, e.g. with wind farms or as decentral storage directly linked to local grids or industrial applications.

Straightforward operating principle

To generate potential energy, a pump raises a piston vertically in a cylinder filled with water. When the imposed load drops it drives a turbine, feeding the energy recovered into the grid. The larger and heavier the imposed load is, the more energy the system can store. If the upload is half as high as the outer cylinder, the maximum energy content of the system results. There is no limit to the number of cycles, and rapid load alternation is perfectly possible. Given its straightforward, robust design, a long service life (> 50 years) and low running costs can be predicted for the Powertower. Storage capacity is scalable, and can be adapted to the specific application on hand. For really large projects several Powertowers can be grouped together in a cluster and controlled collectively; this makes the approach even more cost-effective.

Small-scale tests

A series of small-scale tests at Innsbruck University has established that the system is fully capable of accommodating voltage fluctuations and uneven rates of power supply. A multi-stage plan is envisaged for development to commercial viability.

The first small-scale test was implemented with an external pump turbine, using a plexiglass cylinder 2.20 meters tall and 0.64 meter in diameter, filled with water, and a steel piston with vertical travel, weighing 1.5 tons. The Powertower in the second test is 6 meters tall and 2.30 meter in diameter; it is made of prefabricated concrete elements and has an internal pump turbine. Here the cylinder wall is made of fibre-reinforced plastic.

To work properly the Powertower needs a satisfactory sealing system to ensure that the cylinder cross-section can be closed off 100 %, interrupting flow between the lower and upper reservoirs and preserving the current energy potential. Large Powertowers will need more flexible seals to accommodate geometrical distortions in the cylinder wall.

A large-scale test is currently being prepared, where a Powertower 20 to 30 meters tall and nearly 15 meter in diameter will be realized. The aims here are to show that the system works on a semi-industrial scale, to develop the seal and travel arrangements and to fine-tune the structural and mechanical engineering. The next step will then be to develop a prototype 50 to 100 meters tall with a storage capacity of > 1 MWh. It is intended to achieve commercial viability by 2020, with the option of grouping several Powertowers in a cluster. ◘

Flagship project Tes4seT
New thermal energy storage devices for buildings, industry and transport

Innovative technologies to store thermal energy over the short and long term are essential for energy security and for making energy conversion, energy distribution and end use more efficient. In the Tes4seT flagship project pioneering technologies for a new generation of compact thermal energy storage devices are being researched and strategies developed for integrating them in energy systems in buildings, industry and vehicle engineering. Managed by AEE INTEC, the project brings together nineteen research partners and industrial firms to lay the foundation for further industrial development.

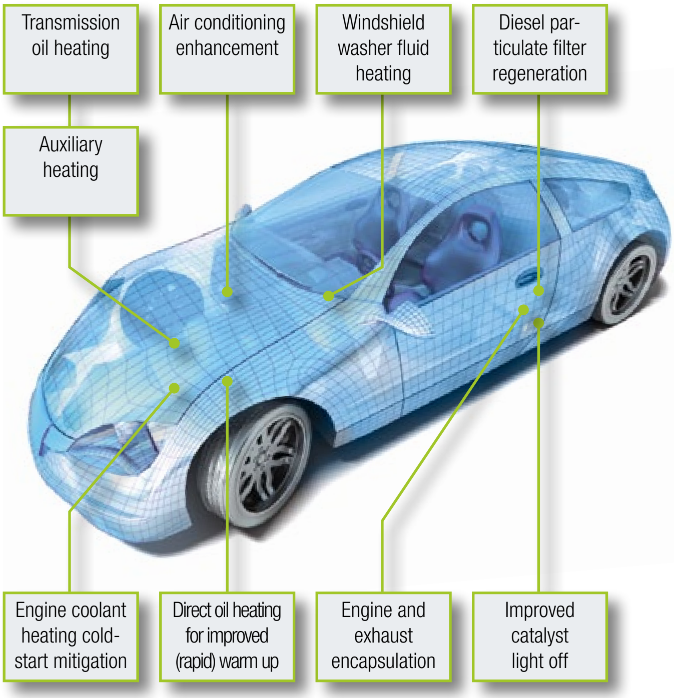
Photo: S.O.L.I.D. – Gesellschaft für Solarinstallation und Design mbH

In the **building sector** the focus is on seasonal solar thermal storage based on sorption technology. New sorption materials for low-temperature applications are being tested, and efficient thermal storage elements for innovative solar collectors developed. Conventional water storage facilities lose a great deal of heat to their surroundings; the new storage systems are intended to achieve better thermal performance and take up less space.

Utilizing waste heat is one important way to boost thermal efficiency in industrial processes. In the **industrial sector** the flagship project involves developing pioneering thermochemical storage technologies and new phase-change materials (PCM) for the medium temperature range. Key industrial sectors such as food, paper and cellulose, machinery and chemicals employ medium-range process temperatures (100 - 250 °C). Steam accumulators are the conventional storage facilities for this temperature range; they operate at high pressure and at only moderate energy density (< 40 kWh/m^3). They have the disadvantage that the temperature varies during charging and discharging, even though many industrial processes require heat at a defined temperature level. PCM storage devices could solve this problem, since heat is stored and released at more or less constant temperature and with high energy density (up to 60 kWh/m^3).

In the **transport sector** new technologies to store energy are of special importance in the case of hybrid and electric vehicles and for rail (including underground rail). Batteries should be charged/discharged in a defined temperature range (around 35°C); if they are colder or hotter, the batteries‘ service life will be shortened. As less heat is available in the case of hybrid and electric vehicles than in vehicles with an internal-combustion engine, efficient heat flow management is needed.

As part of Tes4seT a thermal storage system is being developed to heat and cool a battery pack in electric vehicles, using sorption technology and testing new materials and components to condition the electric battery thermally. The entire system is to be deployed in a simulated car environment.



Thermal sub systems in cars, Source: Alexandr Mitiuc, fotolia.com

Photo: Adrian Pingstone

Photo: Liebherr

„So far storage technologies for air-conditioning have attracted little attention and have scarcely been used at all. From the Tes4seT project we expect new impulses and solutions for implementing storage technologies efficiently and productively in mobile applications – with limits to size and weight – so as to improve the thermal management of air-conditioning equipment. It should be possible to increase passenger comfort and at the same time reduce power consumption in operation.“

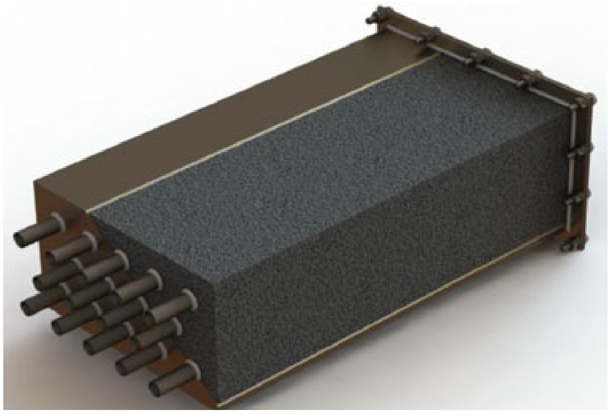
Reinhard Aigner,
Liebherr-Transportation System GmbH & Co KG, Korneuburg

Another area of research involves heat storage for efficient energy systems in rail vehicles. The following topics are being investigated:

> Limiting heat dissipation from underground railways: the aim is to reduce the heat lost from heating, ventilation, air-conditioning and chilling facilities in underground railways by means of thermal energy storage systems.

> Improving conventional air-conditioning systems‘ performance at partial load: a cooling circuit with heat storage is being developed to make it possible to better regulate conventional air-conditioning systems.

> Improving air cycle cooling: conventional air-conditioning units can be made more efficient if the air entering the turbine is dry. New air-drying processes are being developed for this, e.g. employing new zeolites (molecular sieves). ◘



Thermal storage for railway vehicles,
Photo: i2m Unternehmensentwicklung GmbH

FEASIBILITY STUDY

S-chameleonStore
Control platform for multifunctional battery storage systems

The spread of battery storage systems is inhibited by the substantial investment required. Beside of the hardware, configuring a customized storage system is one of the largest cost factors. With the S-chameleonStore technical feasibility study a team of experts at Vienna University of Applied Sciences have laid the foundation for developing a flexible, multi-functional control and configuration platform for battery storage systems. With this platform battery storage units can be configured specifically for the application in question at low cost, making them usable for differing modes of operation. To be able to estimate costs, risks and potential, the team analysed technical, economic, regulatory and ecological issues. Based on the results of S-chameleonStore the implementation project SPIN.OFF will start in 2016, in the context of the funding program “City of Tomorrow”. A zinc bromide redox-flow battery storage unit (with a total capacity of 32 kWh) is to be integrated in the office building “FutureBase” (start of construction summer 2016). This pioneering building, located in Vienna‘s 21st district, will be the first in Austria equipped with a battery unit to store surplus electricity from a photovoltaic facility and to reduce load peaks. ◘

SEES & ScAcaes
New technologies for storing compressed air

Source: TU Vienna

One promising technology for storing electricity is adiabatic compressed-air energy storage, which can be used to supplement pumped-storage facilities on an industrial scale; it achieves up to 70 % efficiency. Work is currently in progress on developing this pioneering technology further in the Institute for Energy Systems and Thermodynamics at Vienna University of Technology. The search is on for a cost-effective, resource-efficient solution that combines full functionality with minimal impact on the surrounding ecosystem.

In the project **SEES – Sublake Electrical Energy Storage** a system has been developed for a flexible compressed-air storage facility that can be installed on the floor of Austrian lakes and operated at constant pressure (isobar). Here heat storage is taken care of by the new SandTES heat storage system, which the project partners have patented. The issue to be investigated (by example of Traunsee, Upper Austria) was whether SEES facilities with a capacity of 1 to 20 MW_{el} can be implemented satisfactorily from an engineering and economic point of view. The project **ScACAES – Saline-Cavern Adiabatic Compressed-Air Energy Storage** investigated the feasibility of using saline caverns resulting from salt extraction as compressed-air storage reservoirs with ACAES equipment. The current and future potential of sites in Austrian Salzkammergut for storing compressed air was assessed and a comprehensive strategy developed, covering both technical and process engineering requirements and

„The particle storage technology developed at Vienna University of Technology and the particle counterflow heat exchanger it includes are ideally suited to use in adiabatic compressed-air energy storage units. However, the field of application for this technology is much wider. Apart from adiabatic compressed-air energy storage many other applications are possible, e.g. for power-to-heat-to-power or for solar thermal power stations. Alongside sand, materials such as corundum can be employed at need. Currently no other fluid-like storage material combines moderate cost with an application temperature range from 5 to 800°C (and more). "

Photo: TU Vienna

Markus HAIDER, Vienna University of Technology, Institute for Energy Systems and Thermodynamics

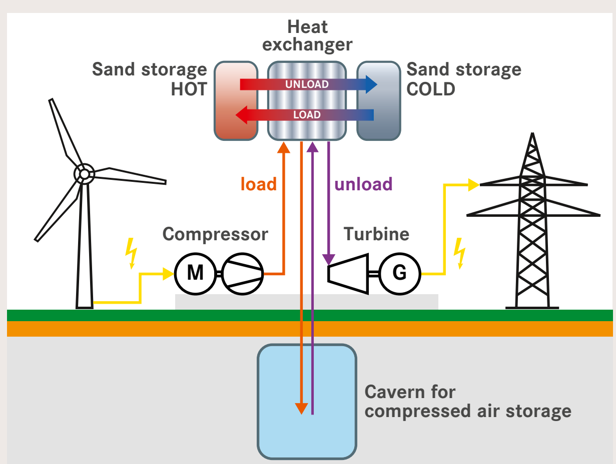
a cost-benefit analysis. The project has yielded a list of usable and interconnectable caverns, with details of the capacity, depending on process implementation.

The recently developed SandTES system is based on active heat storage with sand transported through a heat exchanger. In the case of energy storage on an industrial scale equipment cost is largely dependent on the storage material selected. Sand is a natural product readily available all over the world, and thus an inexpensive storage medium. The sand is fluidized and passed through the heat exchanger over a stationary fluidized bed in counterflow; it behaves like an extremely viscous gas-particle suspension. In the course of the project the entire heat-exchange technology, a special distributor-plate design and a level resp. flow control mechanism were developed, so as to make flexible, dynamic operation possible. The SandTES high-temperature heat exchanger is one of the most important elements for implementing adiabatic compressed-air storage. The commissioning of a first SandTES pilot facility with a capacity of 280kW_{th} is planned for 2016. ◘

TECHNOLOGY

Compressed-air storage power stations use compressed air as an energy storage medium. Off peak, surplus electricity is used to pump air into a reservoir under pressure; when the demand for electricity increases, the compressed air generates electricity in a gas turbine. Until now the heat produced when air is compressed had not been utilized at a later stage; when the air is depressurized additional heat must be supplied externally from a combustion chamber.

In **adiabatic compressed-air storage** the heat released at the compression stage is stored and used at a later stage in the process; before air is depressurized it passes through a heat storage device, where it is heated up. In this way there is no need of natural gas to heat the air with, and the facility achieves greater efficiency.



Source: Vienna University of Technology, Institute for Energy Systems and Thermodynamics

Photo: Sonnenplatz Großschönau GmbH

Photo: Sonnenplatz Großschönau GmbH

On-site consumption cluster

Increasing on-site consumption by means of building clusters and active storage

If more of energy generated from renewables were consumed on-site, problems due to fluctuating rates of feed in to the grid (such as voltage ups and downs, grid overload, transport losses etc.) could be alleviated somewhat. In the project "Eigenlast Cluster" (project management: Sonnenplatz Großschönau GmbH) strategies for increasing on-site consumption of electricity and heat in buildings owned by Großschönau local council and already instrumented for data collection were investigated.

To do this, a total of 27 council buildings, business enterprises and households were grouped together in nine clusters. The buildings' electricity consumption profiles, plus a simulation of the photovoltaic (PV) equipment in place, made up the data baseline. The issues investigated were: which types and combinations of building are suitable for clustering, which is the best size of cluster, how much on-site consumption of electricity is feasible, and how much carbon-dioxide emissions can be reduced. The buildings' profiles ought to fit together in such a way that on-site consumption is maximized. With more variety in consumption patterns there would be more scope for demand-side management measures, too.

Integrating active storage facilities

The assessment also covered the issue of how much on-site consumption of electricity from PV facilities can be further increased by means of long-term hydrogen storage (summer/winter transfer) resp. by short-term battery storage (to balance day/night consumption levels). This was investigated with storage systems provided by the collaboration partner FRONIUS International GmbH. Storage batteries for PV are commercially available today, whereas hydrogen-based storage is still a vision for the future. The complete FRONIUS energy cell (electrolyser and fuel cell in a compact unit), in conjunction with hydrogen storage, takes care of storing electricity all year round.

Potential in clusters of buildings

The project results show that a PV facility can be utilized more effectively if diverse consumers are linked together in a cluster. In the case of fairly small PV units (< 10 kW) on-site consumption can be increased by (on average) 40 % if two extra consumers are tied in. Batteries and hydrogen storage can help to exploit the potential of on-site consumption, even if the costs incurred need to go down for the investment to be justified in economic terms. Below 10 kWh the storage facilities are not yet cost-effective at today's prices. Where clusters feature a large proportion of household consumption, on-site consumption goes up by about 23 % with additional electricity storage (9.6 kWh lithium-ion accumulator). However, including hydrogen storage makes the system less cost-effective, since the hydrogen storage vessels currently available are designed for seasonal storage, and thus involve considerable fixed costs. The simulations also revealed that demand-side management measures can help to make the system more economical.

The project results can be incorporated in the planning process in forward-looking residential building. The experts recommend that building utilization and the technologies for generating and consuming electricity be closely matched to each other as early as the planning stage. ◻

Photo: Sonnenplatz Großschönau GmbH

Storage technologies in the energy system of the future

Photo: Oesterreichs Energie

Barbara Schmidt
Oesterreichs Energie

What changes will our energy systems undergo in future? Will we be able to make more use of electricity from renewables?
Even today, more than 80 % of Austria's electricity is generated from renewable sources of energy. We aim to increase this share to 85 % by 2030, as we expand in the fields of hydropower, wind power and PV. That means ramping up electricity generation from renewables by 20 billion kilowatt-hours per annum, since consumption of electricity will also increase as electricity displaces fossil fuels.

How can fluctuating amounts of electricity from (say) wind and sun be accommodated smoothly in our energy system?
That is a process in which one has to take the long view – with more capacity in transmission and distribution grids, smart systems, an expansion of large-scale storage and increasingly battery storage in the grid and at customers'. Further down the road technologies like power-to-gas will probably come in the system.

What part will electricity storage play in future energy systems?
Storage plays a decisive part. As a first step we need short-term storage for more flexibility, to complement flexible gas power stations. The second step: more capacity in transmission lines, to match demand and regional generation from renewables better. The final step is long-term storage, which will enable us to tide over seasonal fluctuations.

Which new technologies in the field of energy storage have the most potential, in your view?
In the field of short-term storage, definitely battery technologies. For large-scale storage hydropower pumped storage is still unbeatable. Given the huge amounts of energy involved, long-term storage will be feasible only by way of power-to-gas or similar technologies.

What opportunities do you see for technologies involving integrated, comprehensive solutions, e.g. as part of hybrid networks?
As I just mentioned, linking gas and electricity will be vital. That is still a fair way off, though, because energy efficiency is poor here. This is done only if we have such a surplus of electricity from renewables that cannot be accommodated in any other way. However, it is all to the good that research is going on here, as we shall definitely need the link.

energy innovation austria presents current Austrian developments and results from research work in the field of forward-looking energy technologies. The content is based on research projects funded by the Austrian Federal Ministry for Transport, Innovation and Technology and the Climate and Energy Fund. **www.energy-innovation-austria.at** **www.nachhaltigwirtschaften.at** **www.klimafonds.gv.at**

INFORMATION

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