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Current developments and examples of sustainable energy technologies

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Federal Ministry Innovation, Mobility and Infrastructure Republic of Austria

Thermal energy storage – a key component of the future energy system

Innovative developments in Austria

The energy transition demands not only the expansion and integration of renewable energy sources, but also smart solutions for the storage and distribution of electricity and heat. Heat storage systems offer an efficient means of temporarily storing heat energy and providing it in line with demand. They play a key role in decarbonising the heating sector and in stabilising the renewable energy system of the future.

A hybrid storage system is transforming the EVN power plant in Theiß into a future-ready energy hub, photo: C.Stadler/Bwag

New storage technologies
for the heating transition

In future, a large proportion of energy in the energy system will come from fluctuating renewable sources. Energy storage systems will play a central role in facilitating the energy transition, as they can balance fluctuations between energy generation and consumption. High-performance electricity and heat storage systems ensure that energy from renewable sources such as wind, solar or geothermal energy is reliably available at all times. They make it possible to bridge gaps between supply and demand across hours, days and even seasonal timescales, significantly enhancing system stability, security and supply quality. Research and innovation strive to accelerate the development of these key technologies toward market readiness.

In 2024, Austria's total energy demand reached 287 terawatt hours (TWh), with nearly half of this consumed by the heating sector. To date, only about one third of the required heating energy is generated from renewable sources.[1] As a result, heat storage is gaining increasing importance alongside electricity storage systems.

THERMAL ENERGY STORAGE SYSTEMS FOR A WIDE RANGE OF APPLICATIONS

Heat storage technologies can be classified according to the type of storage process and storage media (e.g., sensible heat accumulator, latent heat accumulator, thermochemical storage), as well as by size and application (ranging from short-term to seasonal energy storage systems). Compact heat storage systems such as buffer tanks or latent heat accumulators are used in both houses and apartment blocks, often coupled with heat pumps or solar installations. Large-scale heat storage systems are essential in the decarbonisation of district heating networks. In industry, heat accumulators offer the opportunity to utilise waste heat or temporarily store surplus electricity as heat, enabling the carbon-neutral delivery of process heat.

Sector coupling also plays a key role in long-term energy storage systems. This involves linking different forms of energy supply, such as the electricity sector with the gas and heating sectors, through the conversion and storage of energy. Sector coupling technologies (power-to-heat, power-to-gas) enable the integration of renewable energy sources and increase flexibility within the energy system.

RESEARCH NEEDS AND DEMONSTRATION

Research and development in the field of heat storage technologies aim to reduce investment costs, extend system lifespan, improve efficiency, achieve more compact designs and ensure a high level of system security. Key topics in current national and international research projects include the selection of suitable storage technologies, the development of new materials and components, the integration of storage systems into the energy system and methods for monitoring and operational optimisation. Demonstration plants are crucial to advancing development and facilitating market entry. In addition, appropriate legal frameworks and new business models must be developed.

In this issue, we present several pioneering Austrian projects on heat storage technologies and report on the involvement of Austrian experts in the International Energy Agency's technology programmes on energy storage systems.

Heat accumulator and solar collectors, photo: Arcon-Sunmark

HEAT STORAGE DEMAND IN EUROPE

The demand for heat storage capacity in Europe is expected to grow significantly in the coming years. Projections estimate that Europe's district heating demand will reach approximately 1,780 TWh by 2050 (*EuroHeat and Power, 2018*). Assuming that around 5 to 15 per cent of the annual heat demand needs to be stored temporarily, the necessary storage capacity amounts to approximately 90 to 270 TWh. This would require a total of 22,500 to 67,500 large-scale heat storage systems, each with a water-equivalent volume of 100,000 m^3.[2]

[1] positionen.wienenergie.at/grafiken/energieverbrauch-oesterreich

[2] Source: Nachhaltige Technologien 1/2024, AEE INTEC, p. 6 www.aee-intec.at/zeitung/nachhaltige_technologien-4-2024

Christian Fink, AEE INTEC

on the IEA Energy Storage Technology Collaboration Programme (ES TCP)

Photo: AEE INTEC

Knowledge exchange within the framework of the International Energy Agency's programmes is a key driver of technology development in the field of energy storage systems. AEE INTEC represents Austria in the IEA Energy Storage TCP. What are the objectives and the most important research questions being addressed here?

Energy storage systems constitute a key technology in the transformation of our energy system. Although there has been international momentum in the development of energy storage technology in recent years, there is a need for a significant increase in research activities. And this applies not only to a single storage technology within one energy sector, but across multiple technologies and sectors. Within the Energy Storage TCP, together with our 21 member countries, we aim to initiate the storage developments necessary for the transformation (including electrical, thermal and chemical energy storage as well as system integration), accelerate market introduction through knowledge transfer and collaborate closely with other TCPs. Since exchange with other technology programmes is especially important for a cross-cutting technology like energy storage, our TCP also leads the "Coordination Group on Energy System Flexibility", which currently involves 14 TCPs.

Which heat storage technologies and applications are considered particularly promising?

Most thermal storage applications currently rely on water as the storage medium within a temperature range of 0 to 100 °C, typically using standardised tank storage systems. In numerous application areas, however, this established storage technology is insufficient, making new developments necessary. In the local and district heating sectors, for example, research is currently focused on heat storage technologies capable of holding hundreds of thousands of cubic metres of water, including underground tank storage, aquifers and caverns. Many industrial processes require thermal storage at elevated temperatures (up to 1,000 °C), making this an important area of current research. The storage technologies being developed are also highly relevant for "Carnot batteries" in "power-to-heat-to-power" processes, where heat storage is favoured for its cost advantages. Compact heat accumulators, such as thermochemical materials (TCM) and phase change materials (PCM), offer higher volumetric energy densities or lower weight compared to water, for example, and are needed for applications in buildings, industry and vehicles. Thermally activated building components and cold storage systems also possess strong potential for widespread application and scalability.

In which areas does Austria possess specialised expertise and, therefore, the potential to become an international leader?

Two areas in which Austrian research institutions and companies have developed outstanding expertise in recent years and have also taken on international leadership are:

> the development of large-scale heat storage systems for use in local and district heating networks (including materials research and the development of components and storage system designs);

> the development of high-temperature storage systems as well as compact heat accumulators (materials research, development of reactor technologies, and system integration).

Supporting both cases is the fact that Austrian companies traditionally possess extensive expertise in plant engineering and the construction of complex, large-scale infrastructure.

How do Austrian stakeholders benefit from international exchange?

For a relatively small country like Austria, international research collaborations are particularly important. They not only offer a platform to showcase Austrian expertise globally, but also keep Austrian stakeholders promptly informed about the latest international developments. Moreover, they enable the cultivation of a strong network of international research and industry partners. Complex research questions can be addressed much more rapidly through collaboration, typically leading to significantly better results. Beyond the broader economic advantages, this holds great importance especially for Austrian companies.

Hybrid Storage System in Theiß, photo: EVN, Daniela Matejschek

Theiß energy hub

Hybrid storage systems for a sustainable energy supply

The first phase of the hybrid storage facility at the EVN site in Theiß was officially opened in May 2025. With this, the energy provider is taking the next step in transforming the conventional power plant into a future-ready energy hub. The new storage system is a key technology for the energy transition. Surplus green electricity can be stored here temporarily and used at a later time. This makes the energy supply more secure and independent.

For several years now, the EVN power plant in Theiß, located in the Krems district, has been gradually transforming into a sustainable energy hub. The gas-fired power plant is now used solely for grid support. Since autumn 2023, a new biomass facility has been in operation, supplying Krems with natural heat and green electricity. And since 2024, 5,700 solar panels have been generating solar power. The next step towards a full transition to renewable energy is the deployment of an innovative hybrid energy storage system.

INTERACTION OF ENERGY SYSTEMS

Several years ago, a 5 MW power-to-heat system was installed at this EVN site, using surplus electricity to generate heat. The heat produced can be temporarily stored in the Theiß district heat accumulator if it is not needed immediately. This giga-scale thermal storage system is the largest district heat accumulator in Austria, a specially insulated former oil tank with a capacity of 50,000 m^3 of hot water.

The existing power-to-heat system, which is connected to the giga-scale thermal storage system, has now been expanded with a battery storage unit featuring a power output of 5 MW and a capacity of 6 MWh. The hybrid system integrates storage systems supplied by diverse energy carriers and, together with the biomass cogeneration plant and the newly installed photovoltaic system, establishes a seamless interface between the different energy systems.

The combination of battery and thermal storage systems greatly enhances flexibility. When there is surplus energy in the power grid, the electric heating system is activated; when demand exceeds generation, energy can be drawn from the battery storage unit. The hybrid storage system balances the fluctuating output from renewable energy sources, ensuring security and stability in the grid. At the same time, green electricity can be converted intelligently into heat energy with an efficiency close to 100%. The battery storage system installed in the spring consists of a total of five containers and is just the beginning. In the next phase, EVN plans to significantly expand the system by installing a battery storage system with a power output of up to 70 MW and a capacity of at least 140 MWh.

The new battery storage system, photos: EVN, Daniela Matejschek

> **“Research and development are indispensable for driving innovation in the energy sector. New solutions developed in the lab are first tested and refined on a small scale. They are only rolled out on a large scale and integrated into the energy system once they’ve passed thorough testing. By progressing through multiple stages, this innovation process delivers continuous improvements, while safeguarding the reliability and security of our energy supply. The Green Energy Lab research initiative plays a crucial role by allowing us to test new solutions in real-world operating conditions.”**

ANDREA EDELMANN
HEAD OF INNOVATION, SUSTAINABILITY AND ENVIRONMENTAL PROTECTION, EVN GROUP

Photo: Green Energy Lab/ Stephanie Weinhappel

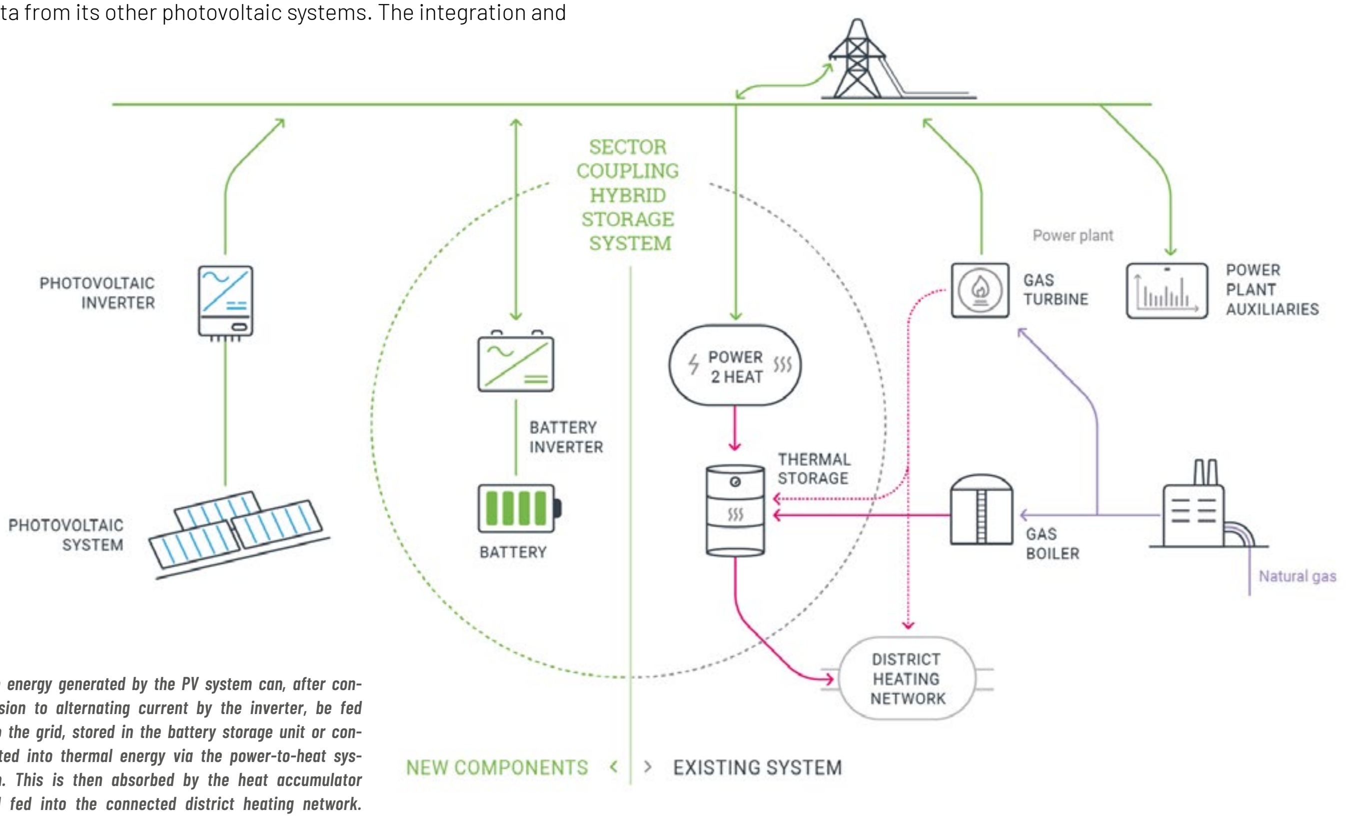
AI-BASED CONTROL SYSTEMS

To develop a comprehensive understanding of hybrid storage systems from technical, scientific and regulatory perspectives, the planning and implementation of the hybrid storage system were scientifically supported by the SEKHOS[1] research project (Theiß sector-coupling hybrid storage system). One of the objectives was to develop business models for marketing the flexibility that can be exchanged between different energy carriers. As part of the research project, artificial intelligence was employed to optimise the control of heat and electricity flows at the Theiß power plant. Machine learning is used to generate forecasts for heat demand and solar power generation. For solar power forecasts, EVN draws on weather data as well as generation data from its other photovoltaic systems. The integration and processing of extensive data form the foundation for evaluating and optimising the operation of the hybrid storage system. The measurement systems will remain in place beyond the conclusion of the research project, continuously providing data for further analysis and use.

greenenergylab.at/projects/sekohs-theiss/?lang=en

[1] **Project partners**: TU Wien/ Energy Economics Group (EEG)(project management), AIT Austrian Institute of Technology GmbH, EVN AG, EVN Wärmekraftwerke GmbH

The SEKHOS THEISS project is part of the Green Energy Lab innovation network. greenenergylab.at



The energy generated by the PV system can, after conversion to alternating current by the inverter, be fed into the grid, stored in the battery storage unit or converted into thermal energy via the power-to-heat system. This is then absorbed by the heat accumulator and fed into the connected district heating network. Image: Green Energy Lab

Drilling operations for the insulated bored pile retaining wall. Various materials are being tested for potential use in the future construction of the heat storage system. Photo: Wien Energie/ Michael Horak

ScaleUp

Vienna plans first mega-scale subsurface heat storage system

Decarbonising district heating is a crucial milestone on the path to achieving climate-neutral heat supply in urban environments. A key technology in this process is the integration of large-scale heat accumulators to temporarily store surplus heat from renewable sources. At present, a consortium led by Wien Energie is investigating the development of a large-scale subsurface heat storage system, planned for mid-term construction at the Donaustadt power plant site.

The district heating system plays an important role in Vienna's heat supply: by 2040, 56 per cent of the city's heat demand is expected to be met through district heating. A large proportion of the heat is currently still generated by fossil-fuel combined heat and power plants and cogeneration plants. The proportion of these plants is set to decrease substantially over the next few years, with their operations transitioning to green gas. Wien Energie aims to harness deep geothermal energy and large-scale heat pumps as alternative heat sources, with the objective of supplying half of the city's future heat demand. For the heating transition to succeed, however, large-scale heat accumulators are essential to increase system flexibility by storing surplus local renewable heat produced in summer and making it available during the winter months. Storing heat beneath the earth's surface is one of several approaches to harness the thermal energy produced in summer for use in winter.

KEY TECHNOLOGY: EARTH BASIN HEAT STORAGE SYSTEM

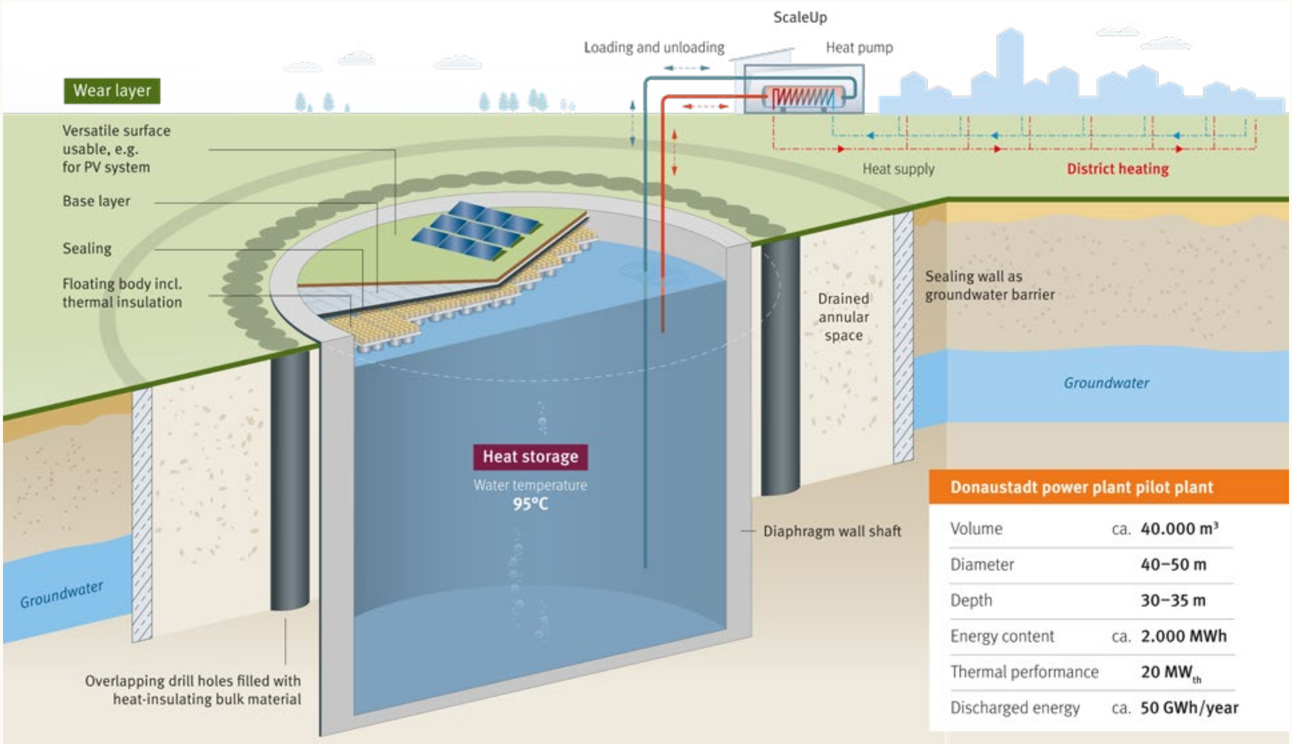
Building on previous research projects and preliminary studies, the ScaleUp[1] project is currently developing the foundations for the construction of an earth basin heat storage system in Vienna's 22nd district. The plan is to construct a storage basin approximately 25 metres deep with a volume of 40,000 m^3 at the Donaustadt power plant site in Vienna.

Earth basin heat storage systems are designed to integrate seamlessly into the urban environment, with their cover surfaces intended for practical use. The project team, led by Wien Energie, is investigating suitable technologies, materials and construction methods, including questions around integrating an earth basin heat storage system into Vienna's district heating network. Both water management and geological aspects are taken into account.

[1] **Project partners**:
Wien Energie (project management), PORR, GeoSphere Austria, AEE INTEC, ste.p

The ScaleUp project is part of the Green Energy Lab innovation network.
greenenergylab.at

The project's implementation is funded by the European Union under the EU Innovation Fund.
ec.europa.eu/assets/cinea/project_fiches/innovation_fund/101190982.pdf



The ScaleUp storage system, source: Wien Energie/APA-Grafik On Demand

Currently, various insulation materials are being tested to enable optimal storage of surplus heat at temperatures of up to 95 °C in the underground storage basin. Furthermore, processes are being developed to upscale the pilot plant, paving the way for the future construction of seasonal storage systems with capacities reaching several hundred thousand cubic metres.

The project also includes the simulation and evaluation of the operational, economic and environmental significance of earth basin energy storage systems within the overall portfolio of district heating producers.

EUROPE'S FIRST PILOT PLANT

Under Wien Energie's leadership, preparations are underway to pave the way for the pilot plant, scheduled for 2029. The underground large-scale heat storage would be the first of its kind in Europe, potentially establishing it as a global leader in this innovative construction approach. The development of the large-scale heat storage system is further supported at the European level. In 2024, the project was selected as one of four Austrian initiatives to receive funding from the EU Innovation Fund.

greenenergylab.at/projects/scaleup/?lang=en

Photo: Wien Energie

"Large-scale heat storage facilities, like those in our ScaleUp and ATES projects, are vital building blocks for Vienna's heating transition. They enable the intelligent storage of surplus renewable heat generated in summer and its supply in line with demand during the winter months. Such technologies provide the necessary seasonal flexibility needed to sustainably reduce the share of fossil fuels in district heating and help us achieve our objective of climate-neutral heat supply."

RUSBEH REZANIA
HEAD OF ALTERNATIVE THERMAL ASSET DEVELOPMENT AT WIEN ENERGIE

ATES – Aquifer Thermal Energy Storage

Storing heat at depth

As part of the ATES Vienna project, Wien Energie investigated the potential of aquifer storage systems for integration into Vienna's district heating network. This innovative technology makes use of thermal water reservoirs located at depths of 600 to 3,000 metres, which are unsuitable for use as drinking water.

Similar to geothermal systems, ATES systems consist of one or more production and injection wells. The key requirement is an underground layer of water-bearing rock or sediment, which serves as a heat accumulator. These aquifers are located over a 1,000 metres below ground in the Vienna region and remain completely isolated from both the surface and groundwater.

CLOSED-LOOP SYSTEM

To store the heat, the thermal water is brought to the surface through a production well and heated there using a heat exchanger. Through another well, known as the injection well, the heated water is returned underground and stored. This creates a closed loop, which operates in reverse during the cold season: when heat demand is higher in winter, the heated water is pumped back to the surface. At the surface, the thermal energy can be extracted and fed into the district heating network, while the cooled water is returned underground.

Within the ATES Vienna[1] project, the groundwork for developing a high-temperature aquifer heat storage system was established, alongside an exploration of opportunities to integrate these storage solutions into Austria's district heating sector.

TECHNOLOGIES FOR URBAN LIVING SPACES

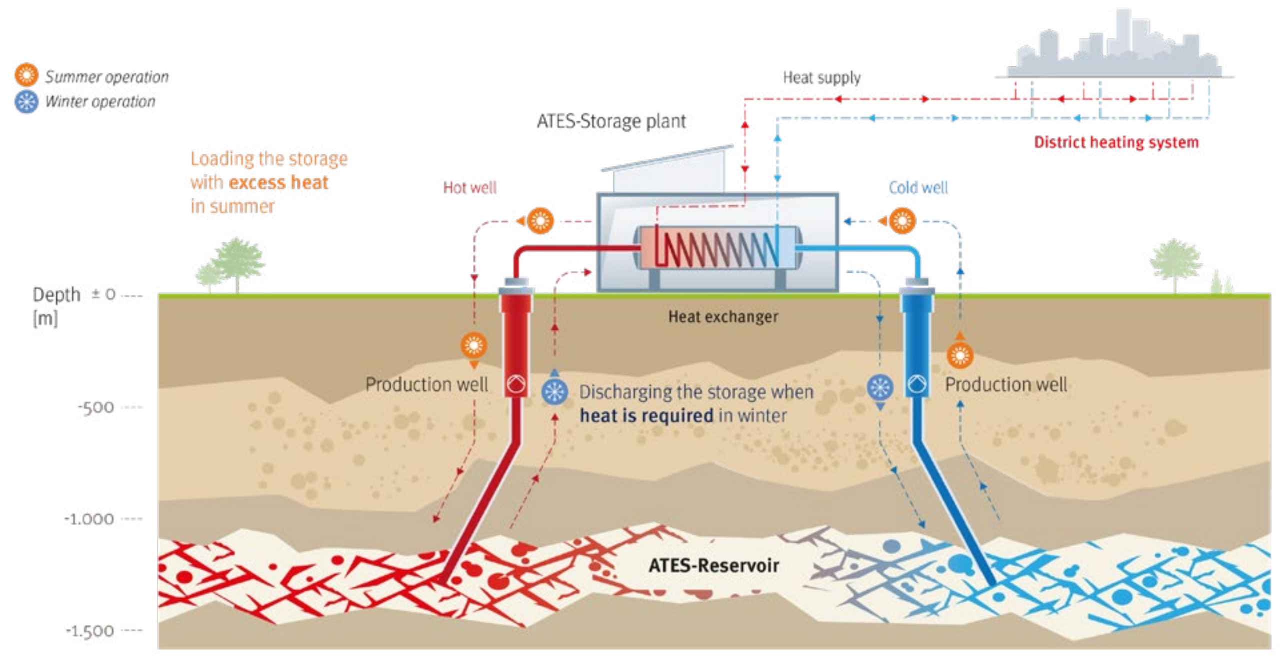
Due to their minimal surface footprint, this storage system solution is particularly attractive for cities where available open space is limited. Alongside specific geological conditions, the presence of suitable energy sources for storage systems and a matching heat demand in the local area are vital. A district heating network or manufacturing companies would be ideal consumers.

In contrast to deep geothermal energy, this technology remains largely underutilised today. Although ATES storage systems have been implemented in select international cases, the Austrian project takes a leading role in advancing research on this innovative concept.

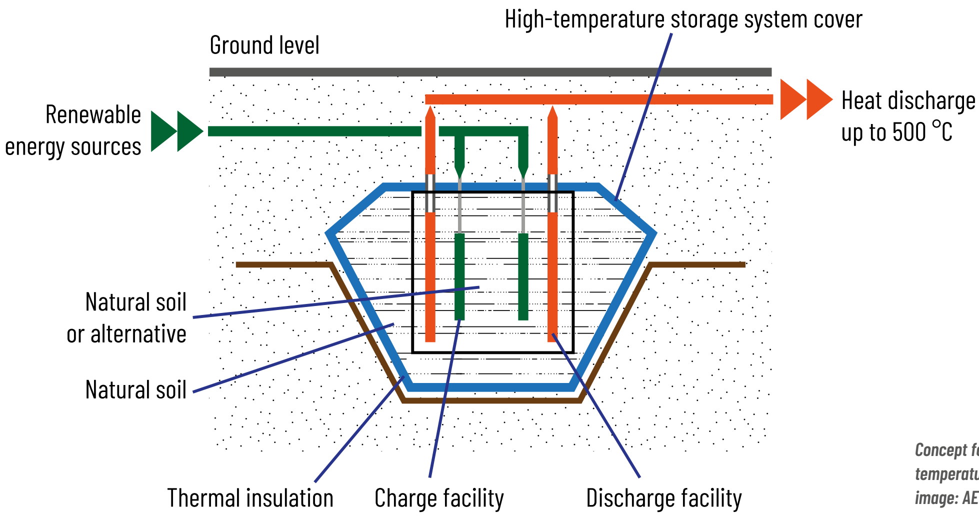
greenenergylab.at/projects/ates-vienna/?lang=en

[1] **Project partners**: Wien Energie (project management), GeoSphere Austria, Geo5, Heinemann Oil, AEE INTEC, AIT Austrian Institute of Technology

The ATES project is part of the Green Energy Lab innovation network. greenenergylab.at



How does the ATES storage system work?, source: Wien Energie/APA-Grafik On Demand



Concept for an underground high-temperature heat storage system, image: AEE INTEC

TESSERACT

New engineering approaches for high-temperature storage systems

Storage system technologies capable of both storing and releasing electricity and heat hold great potential for the future renewable energy system. The TESSERACT[1] project is developing engineering approaches to underground high-temperature storage (UHTS) based on Carnot battery technology.

A Carnot battery is an energy storage system that stores electricity in the form of thermal energy. During the charging process, surplus electricity generated is converted into heat and temporarily stored in a thermal storage system. During discharge, the stored heat is converted back into electricity and/or the waste heat is utilised. The core component of Carnot batteries is the storage system. Various technologies, such as steel containers with gravel packed beds, fluidised beds or PCM high-temperature storage systems, have already been demonstrated in recent years. These above-ground engineering approaches are, however, complex to construct, only scalable to a limited extent and difficult to integrate into natural and urban landscapes.

SUBSURFACE HIGH-TEMPERATURE STORAGE SYSTEM

As part of the TESSERACT project, an interdisciplinary team led by AEE INTEC[2] is developing engineering approaches to scalable underground high-temperature storage (UHTS) tailored to various geohydrological conditions and system integration requirements. For the first time, naturally grown soil is being used as the storage medium. This approach is intended to significantly accelerate construction, reduce costs and enable scalability. The subsurface engineering approaches are being designed and tested for temperature levels of up to 500 °C. This enables broad application in existing energy supply systems, such as in industry or the building sector. Another advantage of the planned UHTS is that the surface above the storage system can be used for multiple purposes, such as construction or development.

RESEARCH AND DEMONSTRATION

The research and demonstration phase, with construction of the storage system scheduled to begin in 2027/28, will mark the first time this innovative concept is comprehensively validated from a technical, economic and legal perspective. The project involves the development of innovative thermal insulation measures and methods for various structural components, specialised civil engineering construction techniques and novel ground heat exchanger solutions. In addition to the wide range of technical and physical criteria, the project also addresses economic and operational questions as well as legal and environmental aspects.

A CONCEPT WITH HIGH POTENTIAL

In the future, this new storage technology has the potential to enable a flexible and intelligent energy system wherever volatile renewable sources are used for electricity supply. The system is scalable in terms of storage volume and integration into existing grid infrastructures. It is especially well-suited for integration with district heating networks in urban areas, industrial and large-scale commercial sectors, as well as for energy communities. The concept therefore makes a significant contribution to the transition to 100 % renewable energy sources.

[1] **T**hermal **E**nergy **S**torage as **S**ensible **E**nergy **R**eservoir in **AC**tivated **T**errain

[2] **Project partners**: AEE INTEC (project management) Ste.p, PORR, Glapor, Windkraft Wolkersdorf (WW) and Biomasse Wolkersdorf (BMW), GeoSphere Austria

LARGE-SCALE HEAT STORAGE TANK
supplies local heating network in Dornbirn

The newly commissioned large volume buffer storage tank by EnergieWerk Ilg GmbH, boasting a storage capacity of around 313 MWh, serves as a showcase project demonstrating advanced construction techniques and the integration of large-scale heat accumulators within sustainable energy systems.

EnergieWerk Ilg GmbH operates several biomass heating plants in Dornbirn to produce both heat and electricity. The heat is fed into the local heating network operated by VKW Nahwärme Dornbirn. As the network continues to expand, both the heat demand and the requirements for peak load coverage are increasing. The existing heating plants operated by EnergieWerk Ilg GmbH have little remaining capacity, which is why the construction of a new heating plant and a large volume buffer storage tank in Dornbirn-Wallenmahd was planned.

The large-scale heat accumulator has been operational since May 2025 and uses water as its storage medium. With a volume of 5,900 m^3, a height of 30 metres and a diameter of 18 metres, new standards have been set in tank construction. The integration of the heat storage system enhances security of supply and minimises the use of fossil fuels for balancing peak loads. Additionally, waste heat from the neighbouring industry can now be utilised. Surplus heat from other plants as well as from the company's own biomass heating plants is temporarily stored and fed into the network as needed.

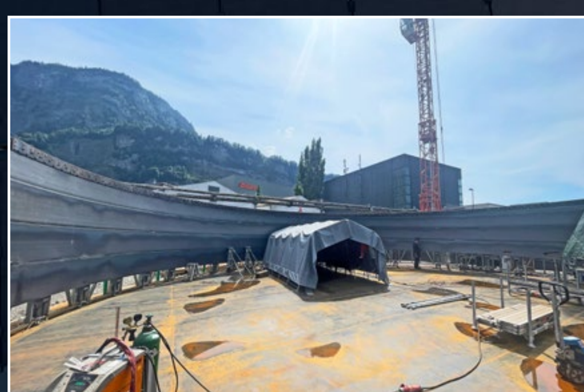
In addition to its role as a heat storage system, the tank will also serve as the central pressure maintenance system for the entire local heating network, further enhancing system stability. The project therefore plays a crucial role in advancing a sustainable, circular and efficient heat supply for the region.

This project is funded by the Climate and Energy Fund under the programmes "Large-scale storage systems" and "Flagship PV projects."

KEY FACTS

Storage system medium: Water
Storage system volume: 5,900 m^3
Max. energy capacity: 313,000 kWh
PV surface area: 1,270 m^2
PV capacity: 250 kWp

INNOVATIVE CONSTRUCTION WITH A PV-CLAD ENVELOPE
A photovoltaic system has been integrated into the storage enclosure. Covering an area of just under 1,300 m^2, specially designed black satin-finish PV modules with a total capacity of 250 kWp have been installed.
Photos: EnergieWerk Ilg



Materials for compact thermal storage systems

Austria's contributions to the IEA research collaboration

Within the framework of the International Energy Agency's research collaboration, new technology developments for energy storage systems are being advanced at the international level. The IEA Solar Heating and Cooling Technology Collaboration Programme's Task 67 project focused on innovative materials for compact thermal energy storage systems (CTES).[1]

Specialists in materials science, component design and system integration collaborated on this project to enhance compact thermal storage technologies and expedite their entry into the market. The project centred on the investigation and optimisation of phase change materials (PCMs) and thermochemical materials (TCMs), which form the foundation of these technologies. More than 80 experts from 16 countries participated in the work across five subtasks. AEE INTEC provided the overall leadership for the project. With the active involvement of numerous Austrian experts, significant progress was achieved across all work packages, laying the groundwork for the further development and future implementation of compact thermal storage systems.

MATERIAL CHARACTERISATION AND DATABASE

Led by the AIT Austrian Institute of Technology, several standardised measurement methods for CTES materials were developed and validated. In addition, the material and knowledge database was significantly expanded and systematically maintained.

[1] nachhaltigwirtschaften.at/en/iea/technologyprogrammes/shc/iea-shc-task-67.php
The project was conducted as a joint, collaborative task under the two Technology Collaboration Programmes (TCPs) for Solar Heating and Cooling and Energy Storage (see p. 3).

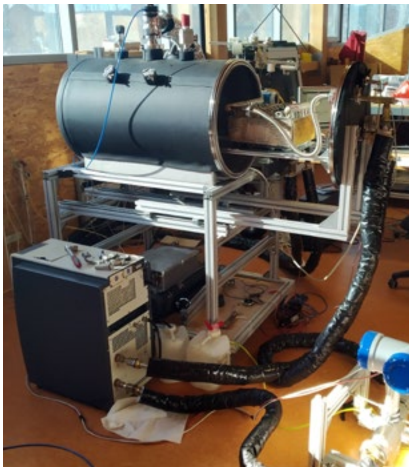
[2] SorSens – Development of a virtual sensor for state-of-charge evaluation of TCM energy storage

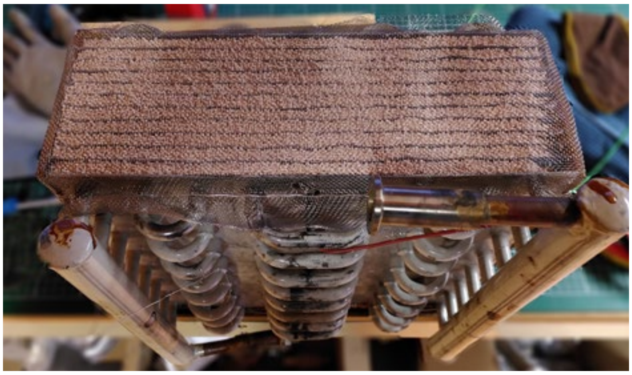
ADVANCING COMPACT STORAGE SYSTEM MATERIALS

This work focused on strategies to tailor the properties of CTES materials to improve their thermal storage characteristics and efficiency. Innovative work in the fields of material and component development was carried out at the Institute of Applied Synthetic Chemistry at TU Wien, leading to the discovery and characterisation of new compact storage system materials from the oxalate and Tutton salt families.

DETERMINING THE STATE OF CHARGE OF COMPACT HEAT STORAGE SYSTEMS

The objective was to develop techniques that can reliably and cost-effectively determine the state of charge of a CTES. The Austrian partners FHOÖ and AEE INTEC developed and tested various methods for determining the state of charge of a sorption storage system within the SorSens[2] project. For all types of energy storage systems, the current state of charge (SoC) is a key parameter for efficient operation and management. Unlike sensible heat accumulators, the state of charge in a thermochemical heat storage system cannot be assessed by measuring the discharge temperature. The moisture content of the material and its distribution throughout the entire storage system serve as a more reliable indicator of the state of charge. Within the project, 26 measurement methods for accurately determining the state of charge in PCM or TCM systems were gathered and classified, and four prototypes demonstrating direct interaction between the material and the control system were presented and reviewed.





Left: vacuum chamber for experiments on the functional prototype of the heat storage system using zeolite. The new sensors are tested using this setup.

Right: functional prototype of the heat accumulator filled with zeolite granules.

Photos: SorSens Endbericht/ AEE INTEC

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