EXPANDED PERLITE AS
Thermal Insulation Shell for Energy Storage Systems

Figure 1 TES technology status and innovation outlook in the power sector (IRENA 2020)

Energy storage plays a crucial role within the contemporary landscape of energy systems. Serving as a linchpin, energy storage addresses the inherent variability and intermittency of RES, such as solar and wind power. By storing excess energy during periods of high renewable energy production and releasing it during high-demand or low-generation periods, energy storage technologies significantly enhance grid stability, reliability, and flexibility (Laura Vallese et al. 2025). This allows the seamless integration of RES into existing power grids, fostering the transition towards a sustainable and low-carbon energy landscape. Various possibilities are available or under development to store energy in different forms. Main heat storage systems are the following:

- Sensible heat storage: Stores energy by raising the temperature of a solid or liquid medium, with the amount stored proportional to its heat capacity.
- Latent heat storage: Stores energy through phase change (e.g., melting /solidification), using the large heat absorbed or released without a temperature change.
- Thermochemical storage: Stores energy in reversible chemical reactions, releasing it upon recombination with high energy density and long-term stability.
- Mechanical–thermal storage: Converts electricity into heat via compression/expansion or friction (e.g., pumped heat, adiabatic CAES), then stores and later reconverts it.

Sensible heat is beneficial as it is the simplest, most mature, and cost-effective method, using abundant natural materials like water, rocks, or molten salts. Indeed, as shown in Figure 1, sensible heat storage combines efficiency in energy storage and low cost with considerable lifetime.

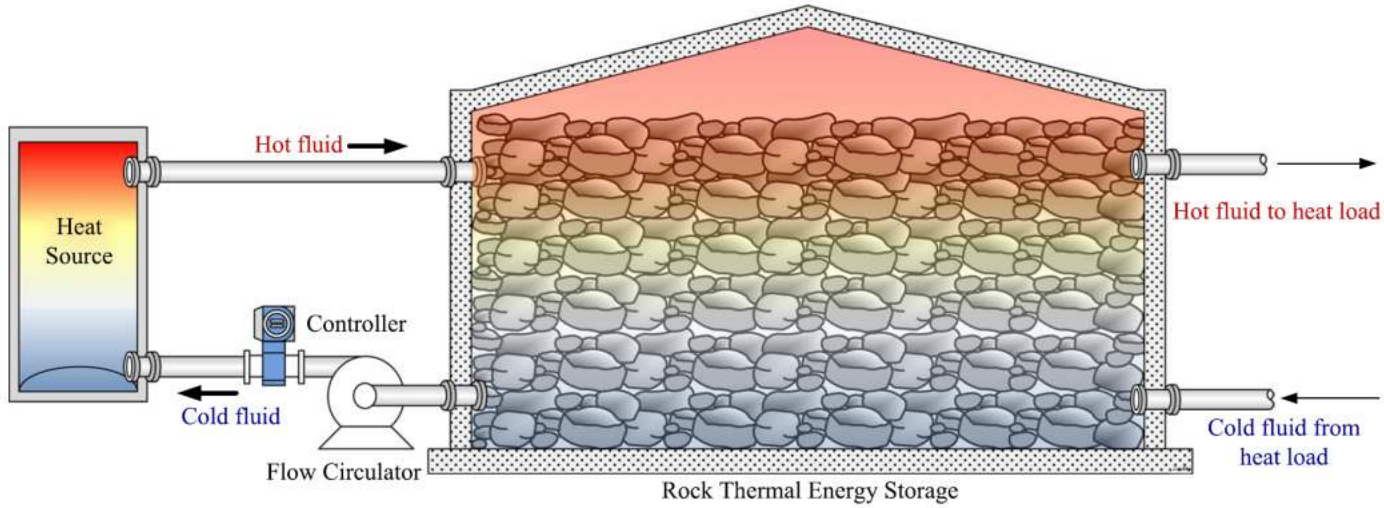

Figure 2 Simplified schematics of a typical rock thermal energy storage (Amiri et al. 2024)

Some Notable Projects

Jämtland, Sweden: ~ 74 kWp solar panels, concrete tower of crushed stones, heated to 600 °C, insulated exterior[1].

Figure 3 Macadam: compacted layers of broken stone of even size for surfacing roads and paths

In December 2023, a farm-scale pilot energy storage system was launched in Jämtland, Sweden by Grow Sverige and partners. A 74 kWp photovoltaic array generates electricity, which is routed to electric heating rods embedded in a large macadam (crushed stone - see Figure 3) bed housed within an insulated concrete tower. These rods heat the stone mass to temperatures of up to 600 °C, effectively storing solar energy as sensible heat. A stainless-steel water circuit extracts heat from the outer stone layers, delivering ~45 °C water to a residential heat pump that supplies space heating and hot water. This demonstrator showcases the potential of using stone-based sensible heat storage, coupled with PV-driven electric heating, as a cost-effective solution for long-term and seasonal energy balancing in cold climates.

Hamburg, Germany: Siemens Gamesa storing renewable energy in 1,000 tons of hot basalt stones[2].

In June 2019, Siemens Gamesa, together with Hamburg Energie and the Hamburg University of Technology, inaugurated an electro-thermal energy storage pilot in Altenwerder, Hamburg, Germany. (See Figure 4) The system uses ~1,000 tonnes of volcanic rock housed in a heavily insulated concrete containment. Excess renewable electricity (e.g. from wind or solar) is converted into hot air via a resistance heater and blower, which flows through the rock bed and raises its temperature (up to ~ 750 °C) — thereby storing energy as sensible heat. When electricity is needed, steam is generated from the stored heat to drive a turbine and re-electrify the grid for up to ~24 hours; the system has a storage capacity of ~130 MWh for several days.

Figure 4 The wind turbine giant Siemens Gamesa has opened a pilot plant for storing electricity in 1,000 tons of volcanic stones. Illustration: Siemens Gamesa.

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1 https://growsverige.se/2023/12/07/lagrad-energi-i-sten/?utm_source=chatgpt.com

2 https://www.siemensgamesa.com/global/en/home/press-releases/190612-siemens-gamesa-inauguration-energy-system-thermal.html?utm_source=chatgpt.com

Denmark / GridScale project: Denmark's largest battery - one step closer to storing green power in stones[3].

The GridScale project, launched in May 2021 in Denmark aims to build the country's largest energy storage facility (~10 MWh) using crushed basalt stones as the storage medium. Excess electricity (from wind or solar) is used to drive a system of compressors and turbines that pump thermal energy: heat is transferred from cool stone tanks to hot stone tanks, raising temperatures to up to ~600 °C, thereby storing energy as sensible heat. (See Figure 5). During discharge, the process reverses, and the heat difference is used to drive turbines or heat exchanges to recover electricity or thermal output. The consortium behind the project includes Stiesdal Storage Technologies, Aarhus University (AU), Andel, DTU, and others, with funding from Denmark's EUDP (Energy Technology Development & Demonstration Program).

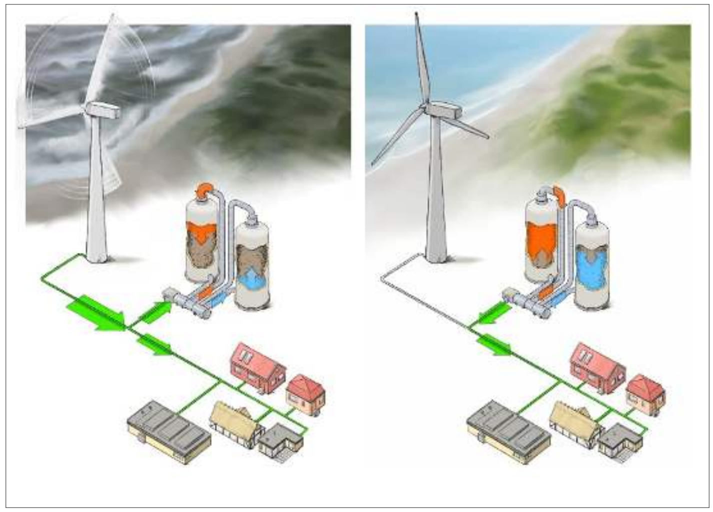

Figure 5 GridScale project principle: When surplus electricity from wind or solar is available, the storage system is charged. Compressors and turbines transfer heat from tanks filled with cool stones to tanks filled with hot stones, cooling the former and heating the latter to temperatures of up to 600 °C. Illustration: Claus Rye, Stiesdal Storage Technologies.

Hot-Water Sensible TES Tanks (Italy) (2024)

Unlike the stone-based projects, the Bolzano (Italy) system by Alperia SpA stores energy in water, which—thanks to its high specific heat capacity—remains a highly effective medium. The installation is a 5,600 m³ insulated cylindrical tank integrated into the district heating network, where heat is stored by raising water temperature and preserved through natural stratification.

The system can operate up to 100 °C (ambient) or 180 °C (pressurized), providing an energy density of 60–100 kWh/m³, efficiencies of 50–90%, and storage durations ranging from daily to seasonal. This makes it a valuable buffer for renewable heat integration and supply security. With low investment costs (0.4–10 €/kWh capacity) and proven maturity (TRL 9), the Bolzano project showcases the scalability of sensible water heat storage for urban district heating.

Figure 6 5600 m3 hot water storage tank in Bolzano, Italy

[3] https://ingenioer.au.dk/en/current/news/view/artikel/denmarks-largest-battery-one-step-closer-to-storing-green-power-in-stones?utm_source=chatgpt.com

The Need for Effective Insulation and the Strong Advantages of Expanded Perlite

In all of the above projects—whether thermal energy is stored in stones, water, or other media—effective thermal insulation is a critical component. Without adequate insulation, stored heat is quickly lost to the environment, reducing system efficiency and making large-scale storage impractical. In particular, when storage systems operate at elevated temperatures, often reaching 500–600 °C, the demands on the insulating material become severe: it must maintain stability without melting or degrading, minimize heat transfer over long durations, and be easy to apply even in large or irregularly shaped containment structures.

Expanded perlite meets these requirements exceptionally well. It is a naturally occurring, sustainable mineral that, once expanded, becomes a lightweight, free-flowing insulating medium. This flowability allows it to fill empty cavities and complex geometries with ease, eliminating gaps where thermal bridges could form. Unlike many other materials, perlite remains effective at very high temperatures (up to ~600 °C and beyond), offering excellent thermal performance without melting or releasing harmful substances. Combined with its low material and installation cost, abundance, and environmental advantages, expanded perlite is an ideal insulating solution for modern thermal energy storage systems, ensuring both efficiency and sustainability.

Temperature		Thermal conductivity	
°F	°C	Btu·in/ h·ft2·°F	W/m·K
0	-17.8	0.4	0.0578
400	204.4	0.6±0.1	0.0865±0.014
800	426.7	1.0±0.2	0.144±0.03
1200	648.9	1.8±0.2	0.26±0.03
1600	871.1	2.8±0.8	0.40±0.12

Table 1 Evolution of thermal conductivity of expanded perlite versus temperature. The range refers to particles with density between 46 and 175 kg/m3 (3-11 lbs/ft³) (2023a)

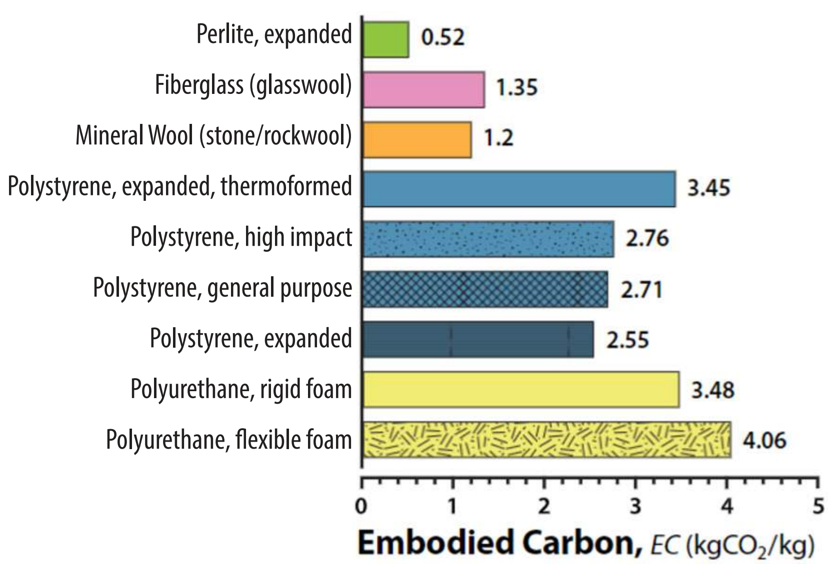

Figure 7 Embodied Carbon of expanded perlite and other insulating building materials (2023b)

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