Thermal energy storage systems

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The different kinds of thermal energy storage can be divided into three separate categories: sensible heat, latent heat, and thermo-chemical heat storage. Each of these has different advantages and disadvantages that determine their applications.

Sensible heat storage (SHS) is the most straightforward method. It simply means the temperature of some medium is either increased or decreased. This type of storage is the most commercially available out of the three; other techniques are less developed.

The materials are generally inexpensive and safe. One of the cheapest, most commonly used options is a water tank, but materials such as molten salts or metals can be heated to higher temperatures and therefore offer a higher storage capacity. Energy can also be stored underground (UTES), either in an underground tank or in some kind of heat-transfer fluid (HTF) flowing through a system of pipes, either placed vertically in U-shapes (boreholes) or horizontally in trenches. Yet another system is known as a packed-bed (or pebble-bed) storage unit, in which some fluid, usually air, flows through a bed of loosely packed material (usually rock, pebbles or ceramic brick) to add or extract heat.

A disadvantage of SHS is its dependence on the properties of the storage medium. Storage capacities are limited by the specific heat capacity of the storage material, and the system needs to be properly designed to ensure energy extraction at a constant temperature.[9]

A single tank with a divider plate to separate cold and hot molten salt is under development.[15] It is more economical by achieving 100% more heat storage per unit volume over the dual tanks system as the molten-salt storage tank is costly due to its complicated construction. Phase Change Material (PCMs) are also used in molten-salt energy storage,[16] while research on obtaining shape-stabilized PCMs using high porosity matrices is ongoing.[17]

Most solar thermal power plants use this thermal energy storage concept. The Solana Generating Station in the U.S. can store 6 hours worth of generating capacity in molten salt. During the summer of 2013 the Gemasolar Thermosolar solar power-tower/molten-salt plant in Spain achieved a first by continuously producing electricity 24 hours per day for 36 days.[18] The Cerro Dominador Solar Thermal Plant, inaugurated in June 2021, has 17.5 hours of heat storage.[19]

A steam accumulator consists of an insulated steel pressure tank containing hot water and steam under pressure. As a heat storage device, it is used to mediate heat production by a variable or steady source from a variable demand for heat. Steam accumulators may take on a significance for energy storage in solar thermal energy projects.

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Solid or molten silicon offers much higher storage temperatures than salts with consequent greater capacity and efficiency. It is being researched as a possible more energy efficient storage technology. Silicon is able to store more than 1 MWh of energy per cubic meter at 1400 ?C. An additional advantage is the relative abundance of silicon when compared to the salts used for the same purpose.[25][26]

Another medium that can store thermal energy is molten (recycled) aluminum. This technology was developed by the Swedish company Azelio. The material is heated to 600 ?C. When needed, the energy is transported to a Stirling engine using a heat-transfer fluid.

"Brick toaster" is a recently (August 2022) announced innovative heat reservoir operating at up to 1,500 ?C (2,732 ?F) that its maker, Titan Cement/Rondo claims should be able cut global CO2 output by 15% over 15 years.[33]

Because latent heat storage (LHS) is associated with a phase transition, the general term for the associated media is Phase-Change Material (PCM). During these transitions, heat can be added or extracted without affecting the material"s temperature, giving it an advantage over SHS-technologies. Storage capacities are often higher as well.

There are a multitude of PCMs available, including but not limited to salts, polymers, gels, paraffin waxes, metal alloys and semiconductor-metal alloys,[34] each with different properties. This allows for a more target-oriented system design. As the process is isothermal at the PCM"s melting point, the material can be picked to have the desired temperature range. Desirable qualities include high latent heat and thermal conductivity. Furthermore, the storage unit can be more compact if volume changes during the phase transition are small.

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