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A Review of Thermal Energy Storage Materials

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Abstract

The goal of thermal energy storage (TES) is to make thermal energy available for later use in heating, cooling, and power production by transferring the energy from one medium to another by either heating or cooling. TES systems have widespread use in the construction and manufacturing sectors. Here, we examine TES technologies that may help increase the value of solar heat while decreasing building energy use. Storage capacity estimation and the basic concepts of numerous energy storage technologies are outlined. Storage solutions that are easy on the environment and your wallet are briefly discussed; they include water tanks, subterranean storage, and packed-bed storage. Thermo-chemical storage and latent-heat-storage systems using phase-change materials for solar space heating and cooling, heat-pump systems, solar water heating, and concentrating solar power plants are also studied. Outstanding data on the efficiency and cost of TES systems, as well as a short overview of cool thermal energy storage, are provided.

Keywords: Compact heat exchanger, Enhancements in heat exchanger, Nano fluid.

Introduction

There are many different types of TES (Thermal Energy Storage) systems and uses for them. How long it has to be stored for, how much it will cost, what temperature it needs to be used at, and how much space you have available all play a role in determining which TES technology to use. The use of TES

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devices and systems in architectural planning and solar power production dates back many years, but their implementation in the automotive sector did not begin until the late 1970s. The automobile sector is ripe for TES's many possible uses. To begin with, the excess heat produced by a running engine may be used to power a TES device. TES devices might also be used to provide heat during warm-up, further reducing fuel use and emissions. The drivers won't need to wait around while the engine heats up. Further, TES gadgets might be used in battery-operated hybrid and electric cars. Since batteries function poorly when temperatures are low, a TES device for quick heating of batteries may be used to mitigate the negative effects of cold weather on battery performance. In the end, a TES device may be utilised to make rides more pleasant for everyone and help defrost windows. Before the inside of a vehicle to be significantly warmed by the internal combustion engine, especially in cold weather, might take several minutes. This problem would be exacerbated for electric cars because of their inability to generate high temperatures. The efficiency with which cars function in the winter is substantially improved by TES devices because to their ability to generate heat independently of other spaces.

Scientists are very interested in TES devices because of the potential they have to reduce harmful effects on the environment and improve the effectiveness of energy usage. Thermal energy storage (TES) devices are able to temporarily store heat in either a hot or cold medium. To close the gap between energy supply and demand, this technology is crucial. The ability of TES devices to recycle energy for use in driving energy systems has clear advantages in the field of renewable energy. They are also useful in preventing the engine from not starting when it is chilly outside. Since TES has several possible uses in the motor sector. To begin with, the excess heat produced by a running engine may be used to power a TES device. TES devices might also be used to provide heat during warm-up, further reducing fuel use and emissions. The drivers won't need to wait around while the engine heats up.

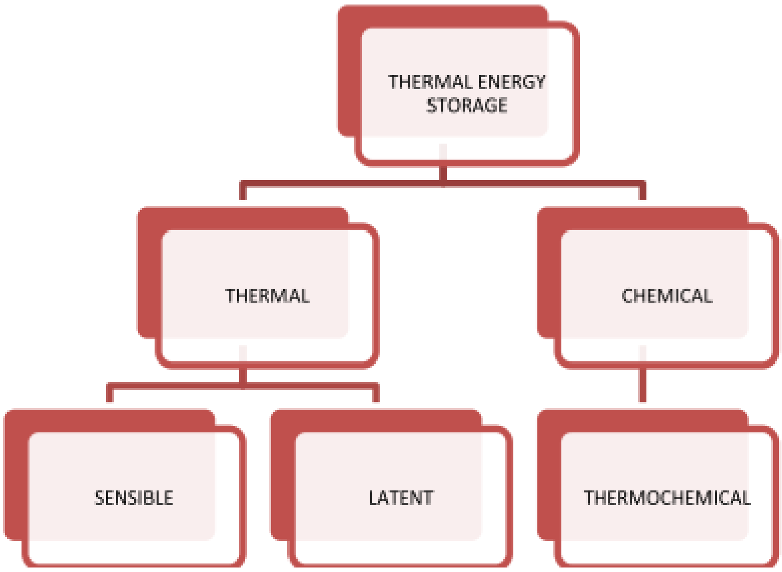

Figure 1: Different types of thermal energy storage device

Sensible Heat Thermal Energy Storage

Heat may be stored in a sensible heat storage device by either increasing or decreasing the temperature of the storage medium. Devices that use sensitive heat TES capitalise on the material's heat capacity and the temperature shift that occurs while charging and discharging. The capacity of a sensible TES device is determined by the beginning and ultimate temperatures of the storage medium as well as its mass and specific heat. Total stored heat may be calculated as:

$$Q=\int_{Ti}^{Tf} mCpdT$$
$$Q= \mathrm{m}\ \mathrm{Cp}\ (T_f - T_i)$$

When it comes to storing sensible heat, water has proven to be the most effective medium so far. Due to its inexpensive price and high heat capacity (4.2 kJ/kg K), it is often utilised in devices that store energy between 20 and 70 degrees Celsius. Water's excellent convective heat transfer properties as a liquid storage medium also enable the storage device to handle larger rates of heat input and extraction. Sensible heat TES devices have been employed in the automobile sector because of their ease of use and inexpensive price. Common practise is to save some hot coolant for use during the cold start, while the engine is otherwise idling. However, the following limitations make sensible heat storage systems poor choices for permanent or automotive applications:

- Low energy storage density (~100 kJ/kg)
- Heavy insulation required to minimize heat loss to the ambient
- Non-isothermal behavior during charging and releasing processes

Thermochemical Energy Storage

For energy storage, thermochemical devices rely on a chemical reaction that can be reversed to release stored energy. In a reversible chemical reaction, it accumulates heat throughout the dissociation process and releases it during the exothermic phase. Although thermochemical storage's benefits have attracted a lot of interest, the technology has yet to enter commercial development.

- No or low heat losses
- Long-term storage period
- Long distance transport possibility
- Small storage volume

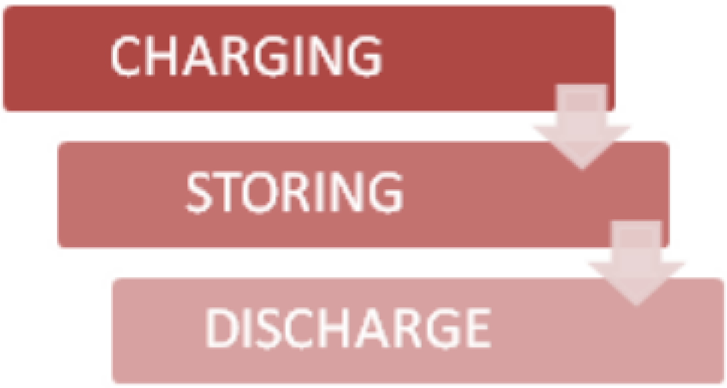

Figure 2: Process of Thermochemical TES Cycle

Latent Heat Storage

Latent heat storage stands out as the most promising of the many possible ways to store thermal energy. Energy is stored in phase change materials (PCMs) via the phase transition that occurs during latent heat TES.

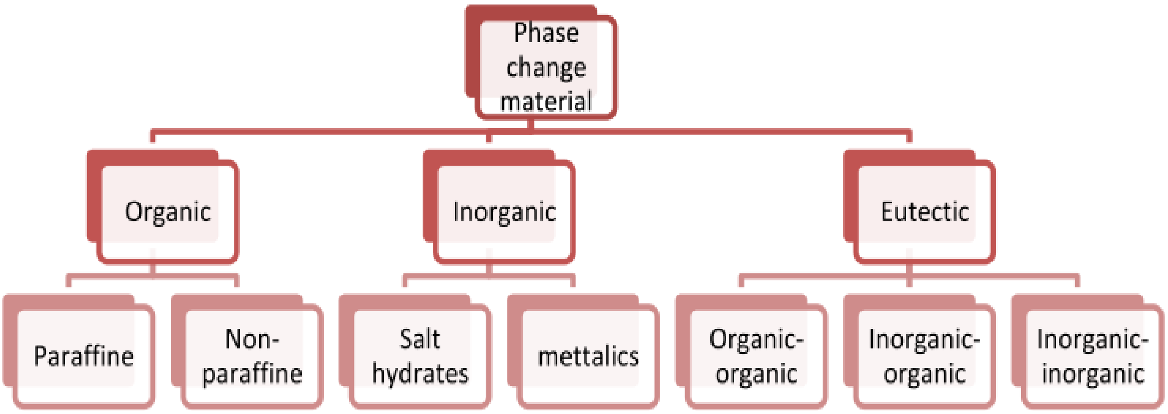

Figure 3: List of most possible materials that may be used for latent heat storage.

The endothermic process involves the substance changing from a solid to a liquid state as the temperature rises. Reducing the temperature causes the substance to shift phase from liquid to solid, resulting in a heat release. Since PCMs store energy as latent heat of fusion, the heat release mechanism has little effect on the surrounding temperature. The energy storage process necessitates many phase changes, including solid-solid, solid-liquid, solid-gas, and liquid-gas. It is the crystalline alteration of the material that stores the energy during the solid-solid transition. The latent heat and volume changes during this transformation are negligible. So, solid-solid PCMs benefit from more design freedom thanks to looser container restrictions. However, solid-liquid transition is significant in latent heat TES because to its large energy storage density and much greater latent heat of fusion. Solid-gas and liquid-gas phase transitions have a greater latent heat of fusion than solid-solid and liquid-liquid transitions, however the substantial volume shift that occurs during the phase change process makes designing a practical storage device more challenging.

Applications

- Collecting and storing heat from the sun was formerly the sole practical use of solar power; this was accomplished by directing the sun's rays through a series of tubes within a solar collector. When it comes to storing heat energy, this method is one of the more temporary options that can be used for a specific task only temporarily.
- Using phase change materials to keep a building at a constant temperature requires first creating a cavity in the wall and then applying a thin coating to keep the inside at a consistent temperature for an extended length of time. It is possible to alter the temperature of a space by applying an insulating coating to the inside or outside of a wall.
- In the 18th century, when artificial cooling was in short supply, people turned to the vapour absorption refrigeration system, which involved heating ammonia with collected solar radiation and then passing it through an evaporator chamber, where the vapour absorbed the heat and lowered the temperature of the chamber. Food was preserved because the temperature was so low compared to the surrounding air.
- Heat is reclaimed from combustion byproducts and used for secondary heating in the process known as thermal energy recovery.

Cool Thermal Energy Storage

Recent research has focused on the potential of cool thermal energy storage (CTES) in commercial and industrial refrigeration settings, particularly in process chilling, food preservation, and HVAC applications. In the range of 5 to 15 degrees Celsius, sensible heat storage materials are superior than latent heat storage materials, making them ideal for use in air cooling and refrigeration (ice storage) (like water).

To balance energy supply and demand, CTES looks to be a viable option. An improved insulating tank is necessary for cooling energy storage since the cool state's energy is more costly than the heat state's. As part of their research, Cheralathan et al. looked at how well CTES worked with an industrial refrigeration system. Costs of both capital and operation may be reduced by using integrated thermal storage systems, as was pointed out by the authors. Compared to a chilled water system, the PCM-based CTES system is far more compact. There are several benefits of incorporating CTES into energy systems and buildings. When cooling storage is included into district cooling systems, CTES has the potential to play a significant role in the control of peak demands and the solution of the intermittency issue of renewable energy sources.(Sarbu & Sebarchievici, 2018)

TES may also make use of the sorption phenomena. Dissociation (an endothermic process) is then facilitated by the application of heat, and the components of the working pair may be kept in separate storage containers. Again, they generate heat upon contact (exothermic process). Since heat is not stored in a perceptible or latent form but as potential energy, it may be held with little loss as long as the components are maintained apart.

Literature Review

(Kumar & Shukla, 2015) The low density of solar radiation at Earth's surface, and its erratic character depending on the time of day and season, are major contributors to these kinds of problems. Solar thermal power applications would benefit greatly from the addition of a solar energy storage unit in order to avoid these problems.

(Chavan et al., 2018) Different types of characterisation research, experimental work, numerical investigations, and patents are reviewed to assess the performance of storage systems. There have been numerous techniques reviewed and discussed in order to improve thermal performance.

(Sarbu & Sebarchievici, 2018) TES systems have widespread use in the construction and manufacturing sectors. Here, we examine TES technologies that may help increase the value of solar heat while decreasing building energy use. Storage capacity estimation and the basic concepts of numerous energy storage technologies are outlined.

(Prasad et al., 2019) New developments in these types of storage systems will be presented in this review article. This paper will examine and debate the many forms of storage that have been invented, including latent heat storage (LHS),thermochemical storage (TCS), and sensible heat storage (SHS) (SHS). However, whereas SHS has been widely adopted and marketed, TCS is still in its infancy.

(Chavan et al., 2015) In this study, we examined the following three facets of the development of thermal energy storage methods: Methods of storage, categorization, and uses.

(Avghad et al., 2016) Not only can energy storage help close the gap between supply and demand, but it also improves the efficiency and dependability of power grids. It results in less wasted energy and capital, which in turn saves money on premium fuels and improves the system's efficiency. Phase change materials (PCMs) are becoming more popular for storing thermal energy because of the significant role they play in achieving energy savings in buildings while maintaining thermal comfort.

(Kampouris et al., 2020) It may aid in the reduction of emissions across several economic sectors and assist to the efficient use of generating and grid assets. By supporting energy security, a robust internal energy market, and the effective integration of additional carbon-cutting renewables, energy storage may assist the European Union (EU) achieve its goals for efficient energy usage.

(Moldgy & Parameshwaran, 2017) Solar power production, however, is impractical due to issues including poor energy density, volatility in energy output, and supply-demand mismatch. In this study, we give a review and presentation of current advancements in solar thermal and solar photovoltaic systems using thermal energy storage (TES) for heating applications.

(Lebedev et al., 2018) Due to the intermittent nature of many renewable energy sources and the depletion of certain energy sources, it is crucial that advances in energy storage technology be made in order to effectively convert and use the energy that is currently accessible. Phase change materials (PCMs) are an exciting new development in the field of thermal energy storage. We provide a categorization of phase-change materials. One of the necessary significant aspects is the shape of the container holding the PCM.

(Sood et al., 2022) As a consequence of employing a smaller engine with a lower total energy conversion, there will be less heat available to warm up the passenger compartment and the engine, but this may be mitigated with the use of modern technologies, such as exhaust conditioning devices and design modifications. A rising importance in society is being given to the contribution it has made to raising the living standard.

Conclusion

This research concludes the following:

1. Latent heat TES devices are most useful for storing excess heat produced by an automobile engine during operation; this heat may then be used to preheat the engine before it is started, even in low temperatures.
2. To improve upon the qualities of single PCMs like paraffin wax etc., composite PCMs are used. A more effective thermal energy storage unit may be developed if composite phase transition materials are given the attention they deserve.
3. A system for storing thermal energy using latent heat can hold anywhere from 5-14 times as much heat as a system for storing thermal energy using sensible heat.
4. For the best possible thermal energy storage unit, it is crucial to carefully select the phase change material (PCM) and ensure that it is compatible with the containment in which the PCM will be encased.

SHS may be used for home heating, community heating networks, and commercial and industrial applications. Water is the most widely used and well commercialised heat storage medium because of its many useful uses in both domestic and industrial settings. Sensible heat is stored underground in liquid and solid mediums for generally large-scale uses. However, the storage capacity of SHS-based TES devices is limited by the storage medium's specific heat. In addition, SHS systems need to be thoughtfully designed so that they can release thermal energy at stable temperatures.

Latent heat from a phase transition may be used to increase the storage capacity of phase change materials (PCMs). Because the phase change temperature remains constant, PCMs also allow for a temperature-targeted discharging process. Thermo-physical concerns, melting point, and latent heat of fusion are the three most fundamental criteria affecting the selection of PCMs for any given application. Among the most important criteria for being chosen are a high heat of fusion and a consistent melting/solidification temperature (without subcooling). An improved heat transfer rate has been obtained via a number of promising mechanical and nano-level improvements. Micro-encapsulation is an answer to the problem of phase segregation in salt hydrates, since it increases the surface area available for heat transmission.

The vast majority of published works deal with commonplace and commercially available PCM substances like paraffin. Synthesizing specialised PCMs appropriate for certain construction applications and concentrating on those with a broad temperature range, such as salt hydrates, are both something we think should be prioritised.

References

Avghad, S. N., Keche, A. J., & Kousal, A. (2016). Thermal Energy Storage: A Review. *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE*, *13*(3), 72–77. https://doi.org/10.9790/1684-1303027277

Chavan, S., Gumtapure, V., & Perumal, D. A. (2018). A Review on Thermal Energy Storage Using Composite Phase Change Materials. *Recent Patents on Mechanical Engineering*, *11*(4), 298–310. https://doi.org/10.2174/2212797611666181009153110

Chavan, S., Panwar, V., & Rathod, R. (2015). Review on Thermal Energy Storage Techniques. *International Journal of Engineering Development and Research*, *3*(4), 2321–9939. www.ijedr.org

Kampouris, K. P., Drosou, V., Karytsas, C., & Karagiorgas, M. (2020). Energy storage systems review and case study in the residential sector. *IOP Conference Series: Earth and Environmental Science*, *410*(1), 0–11. https://doi.org/10.1088/1755-1315/410/1/012033

Kumar, A., & Shukla, S. K. (2015). A Review on Thermal Energy Storage Unit for Solar Thermal Power Plant Application. *Energy Procedia*, *74*, 462–469. https://doi.org/10.1016/j.egypro.2015.07.728

Lebedev, V. A., Elsayed, A., Amer, A., & Lebedev, V. (2018). Thermal Energy Storage by Using Latent Heat Storage Materials. *International Journal of Scientific & Engineering Research*, *9*(5), 1442–1447. http://www.ijser.org

Moldgy, A., & Parameshwaran, R. (2017). Solar thermal energy storage for heating applications - A review. *International Conference on 21st Century Energy Needs - Materials, Systems and Applications*, *ICTFCEN 2016*. https://doi.org/10.1109/ICTFCEN.2016.8052744

Prasad, D. M. R., Senthilkumar, R., Lakshmanarao, G., Krishnan, S., & Naveen Prasad, B. S. (2019). A critical review on thermal energy storage materials and systems for solar applications. *AIMS Energy*, *7*(4), 507–526. https://doi.org/10.3934/energy.2019.4.507

Sarbu, I., & Sebarchievici, C. (2018). A comprehensive review of thermal energy storage. *Sustainability (Switzerland)*, *10*(1). https://doi.org/10.3390/su10010191

Sood, T., Verma, R., Singh, Y., Kumar, P., & Kumar, R. (2022). A review on thermal energy storage. *AIP Conference Proceedings*, *2357*(2), 1540–1544. https://doi.org/10.1063/5.0080582