A Review on Thermal Energy Storage and Impact on Environment

Vikas Kumar and MD.Ahtasham*

School of Energy and Environment
Rajiv Gandhi Vishwavidyalaya Bhopal-462033
India

A B S T R A C T

Energy storage now a day is becoming an imperative part of renewable energy because of a rapidly increasing population over the world. Energy storage systems are needed to ensure stability, reliability and quality of electrical systems. The contribution of renewable energy systems in meeting Global electrical needs in view of the depleting fossil fuels and environmental issues. This paper describes the types of thermal energy storage technology, principles of several energy storage methods capacities are described, advantage and disadvantage, technical issue and impact on our Environment.

INTRODUCTION

In the present scenario when the demand is more than resources available, it's our necessity to develop an energy storage device to store energy at the time of availability and supply it whenever demand is more than available supply and we to have considered all parameter related to our day to day life and impact of our environment. Energy is the major source for the economic growth of any
nation. India is second most populated country, which is 18% of the global population and consumes only 6% of the global primary energy Rapid increase in population and enhanced the living standard of life led to the energy consumption upsurge in India, making it fourth in energy consumption in the world. India is among top three power generating nations in the world with a total installed capacity of 314GW as of January 2017. In the last six decades, Indian energy consumption has reached 16 fold and installed capacity by 84 times. A next-generation smart grid without energy storage is like a computer without a hard drive, severely limited. Accordingly, the energy storage market is set to
"explode" globally in the next decade as indicated by market researchers. Energy storage deployments in emerging markets worldwide are expected to grow over 40 per cent annually in the coming decade, adding approximately 80 GW of new storage capacity to the estimated 2 GW existing today energy sources like energy from wind, sun and water do not contribute to carbon emissions directly, it is not easy to directly utilize energy generated from these sources.

Also, it is not only important to generate energy from renewable sources but also important to store the generated energy. This is because these sources of energy are not stable; they have intermittent supply. For example, solar energy is only available during the day. It is therefore important to store part of the energy generated during the day; otherwise, it will be wasted. The same thing can be said for wind, water and other renewable energy sources where and whenever they are available.

Investigations on ways to make them always available are therefore vital to satisfy our energy demands. Energy storage is not only important in developed countries, but also in developing countries, where there is no access or inadequate access to electricity. This makes energy storage very important to mankind. Energy storage helps to improve the development and utilization of renewable energy, and sustainable technologies.
Energy supply and use are related not only to problems such as global warming but also to such environmental concerns as air pollution, ozone depletion, forest destruction, and emissions of radioactive substances. These and other environmental issues must be taken into consideration if human society is to develop in the future while maintaining a healthy and clean environment. Much evidence suggests that the future will be negatively impacted if people and societies continue to degrade the environment.
There is an intimate connection between energy, the environment, and sustainable development.

A society seeking sustainable development ideally must utilize only energy resources that cause no environmental impact (e.g., which release no emissions or only harmless emissions to the environment). However, since all energy resources lead to some environmental impact, it is reasonable to suggest that some (but not all) of the concerns regarding the limitations imposed on sustainable development by environmental emissions and their negative impacts can be overcome through increased energy efficiency. A strong correlation clearly exists between energy efficiency and environmental impact since, for the same services or products, less resource utilization and pollution is normally associated with higher efficiency processes.

Thermal energy storage (TES) systems can contribute significantly to meeting society’s needs

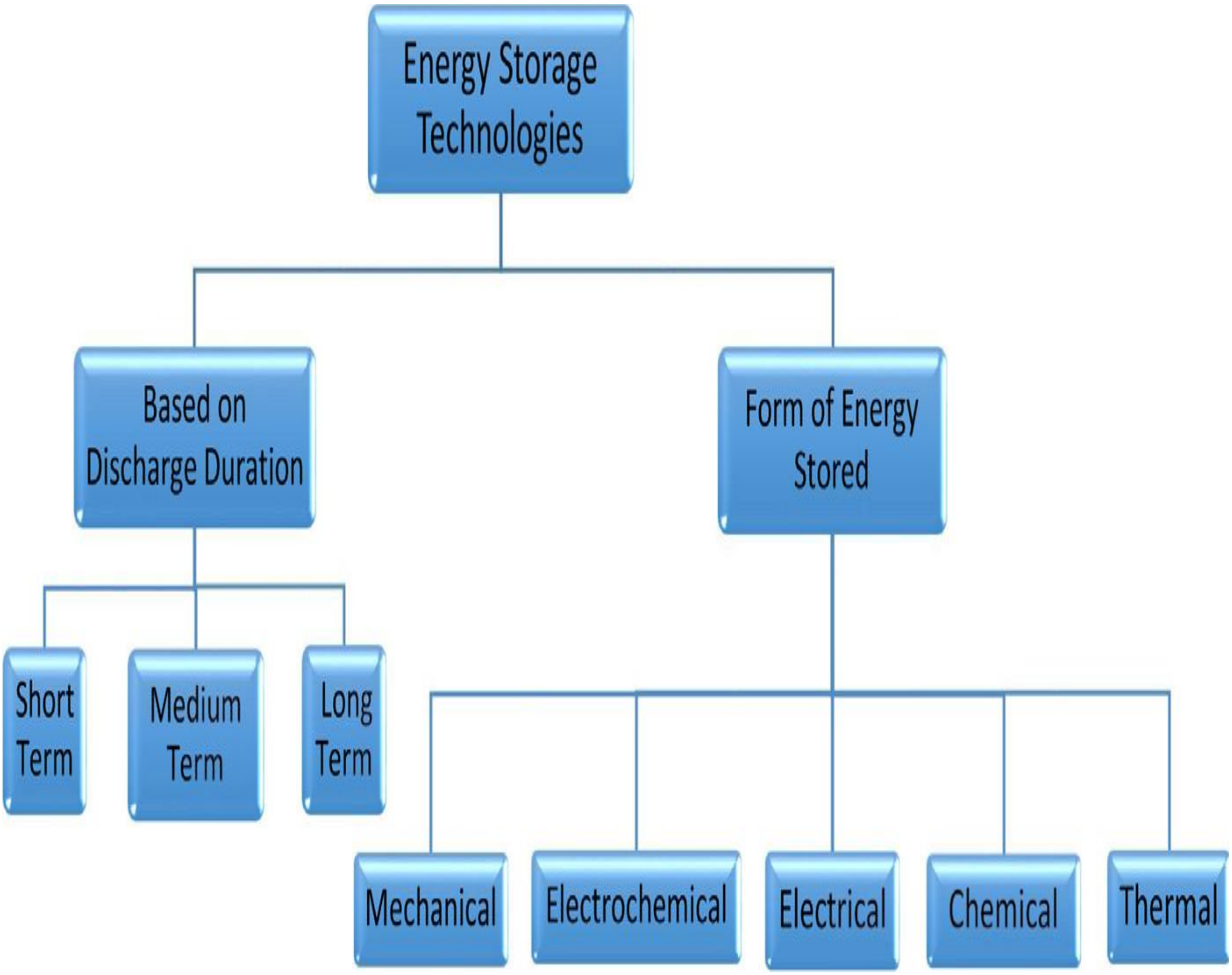
and desires for more efficient, environmentally benign energy use in such applications as building heating and cooling and electric power generation and distribution.

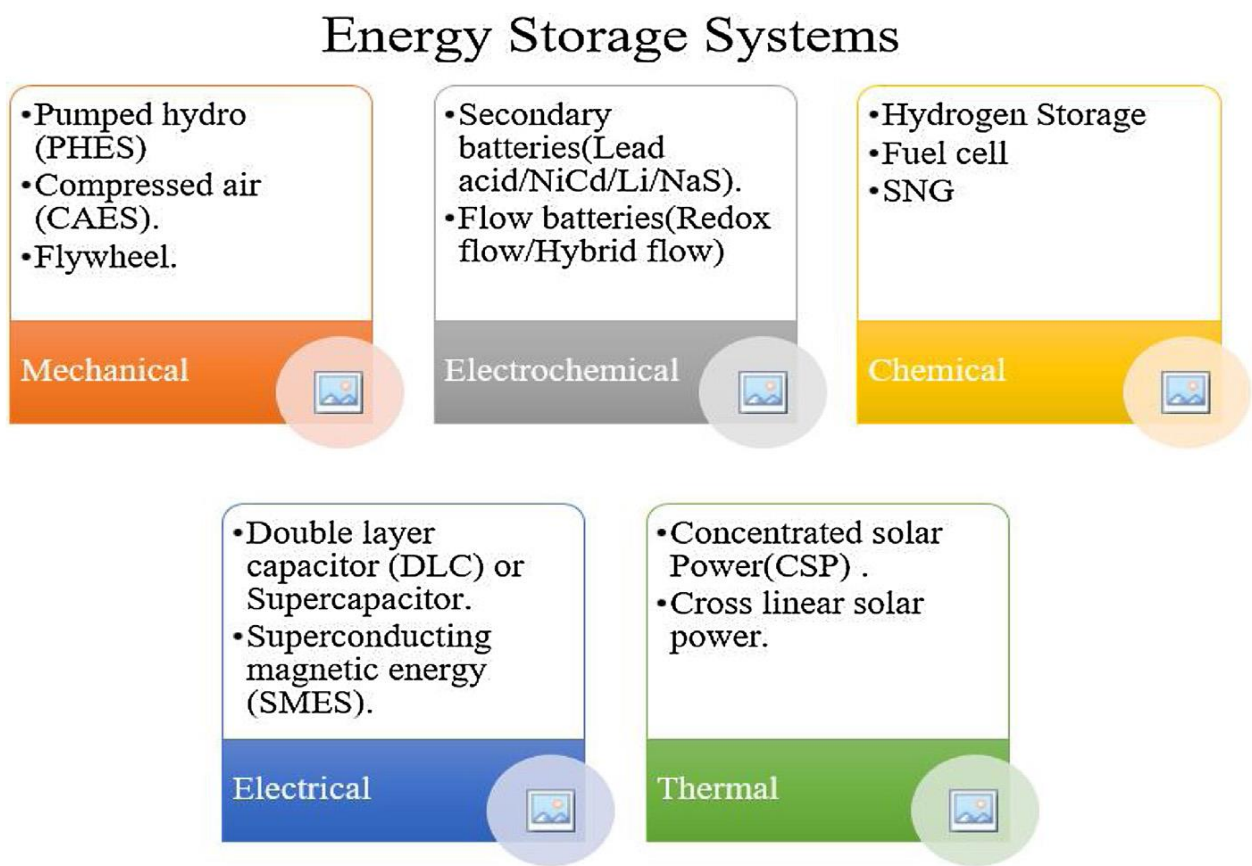
The use of TES systems often results in significant benefits, such as the

- reduced energy costs;
- reduced energy consumption;
- improved indoor air quality;
- increased flexibility of operation;
- decreased initial and maintenance costs;
- reduced equipment size;
- more efficient and effective utilization of equipment;
- conservation of fossil fuels (by facilitating more efficient energy use); and

Energy Storage Technology

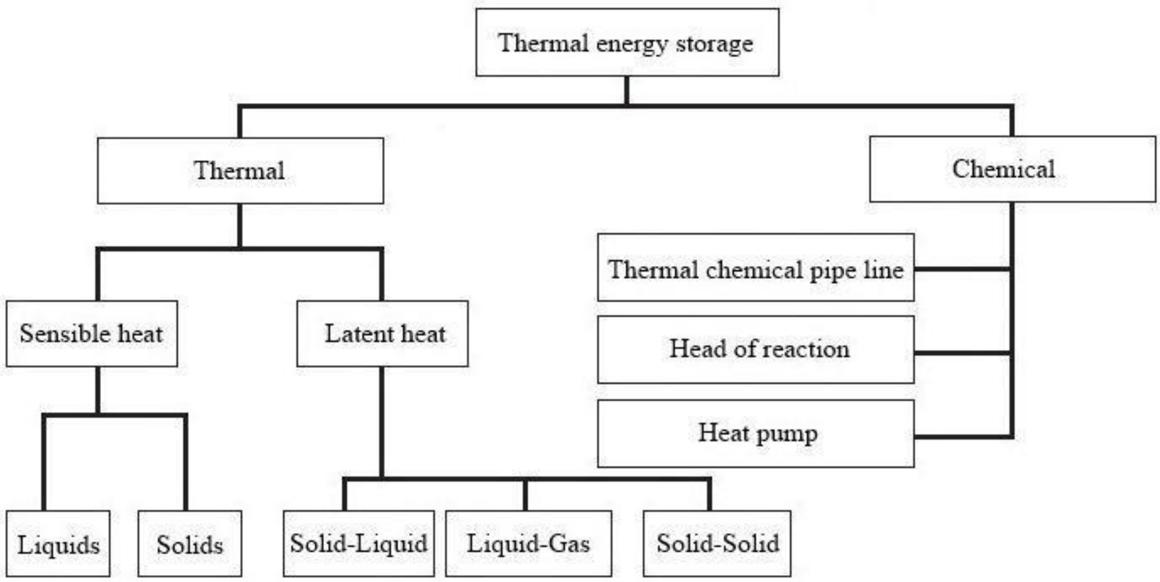
Storage is a major issue with the increase of renewable but decentralized energy sources. There are we discussed the many storage technologies and basically discussed the thermal energy storage





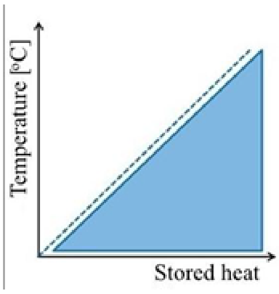
Thermal Energy storage

Large scale thermal energy storage like underground thermal energy storage (UTES) and a system based on phase change materials named as latent heat storage (LHS). The common thermal storage systems like Borehole Thermal Energy Storage (BTES), Aquifer Thermal Energy Storage (ATES), Tank Thermal Energy Storage (TTES) and Pit Thermal Energy Storage.



Sensible heat storage

SHS is the simplest method based on storing thermal energy by heating or cooling a liquid or solid storage medium (e.g., water, sand, molten salts, or rocks), with water being the cheapest option. The most popular and commercial heat storage medium is water, which has a number of residential and industrial applications. Underground storage of sensible heat in both liquid and solid media is also used for typically large-scale applications. SHS has two main advantages: it is cheap and without the risks associated with the use of toxic materials.

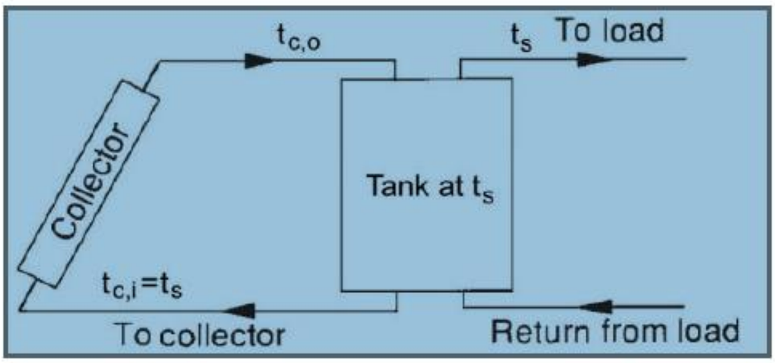


SHS system utilizes the heat capacity and the change in temperature of the storage medium during the process of charging and discharging. The amount of heat stored depends on the specific heat of the medium, the temperature change, and the amount of storage material.

SHS liquid available because it is inexpensive and has high specific heat. However, above 100 °C, oils, molten salts, and liquid metals are used. For air heating applications, rock bed type storage materials are used.

Water Tank Storage

The most common material used in a sensible heat storage system is water. The use of hot-water tanks is a well-known technology for thermal energy storage. Hot-water tanks serve the purpose of energy saving in water heating systems via solar energy and via co-generation (i.e., heat and power) energy supply systems. State-of-the-art projects have shown that water tank storage is a cost-effective storage option and that its efficiency can be further improved by ensuring optimal water stratification in the tank and highly effective thermal insulation.



The energy storage capacity of water (or other liquid) storage unit at a uniform temperature (i.e., fully mixed or no stratified) operating over a finite temperature difference is given by Equation (1) redefined as

$$Qs = Mcp\Delta ts$$

where Q_s is the total heat capacity for a cycle operating through the temperature range Δt_s, and m and c_p are the mass and the specific heat, respectively, of water in the unit.

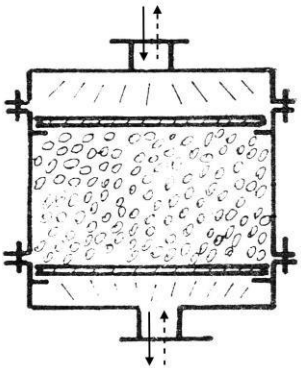
Underground Storage

Underground thermal energy storage (UTES) is also a widely used storage technology, which makes use of the ground (e.g., the soil, sand, rocks, and clay) as a storage medium for both heat and cold storage. Means must be provided to add energy to and remove it from the medium. This is done by pumping heat transfer fluids (HTFs) through pipe arrays in the ground. The pipes may be vertical U-tubes inserted in wells (boreholes) that are spaced at appropriate intervals in the storage field or they may be horizontal pipes buried in trenches. The rates of charging and discharging are limited by the area of the pipe arrays and the rates of heat transfer through the ground surrounding the pipes. If the storage medium is porous, energy transport may occur by evaporation and condensation and by the movement of water through the medium, and a complete analysis of such a store must include consideration of both heat and mass transfer. These storage systems are usually not insulated, although insulation may be provided at the ground surface.

Packed-Bed Storage

A packed-bed (pebble-bed) storage unit uses the heat capacity of a bed of loosely packed particulate material to store energy. A fluid, usually air, is circulated through the bed to add or remove energy. A variety of solids may be used, rock and pebble being the most widely used materials.

A pebble-bed storage unit is shown in Figure5. In operation, flow is maintained through the bed in one direction during the addition of heat (usually downward) and in the opposite direction during removal of heat. Note that heat cannot be added and removed at the same time; this is in contrast to water storage systems, where simultaneous addition to and removal from storage is possible.



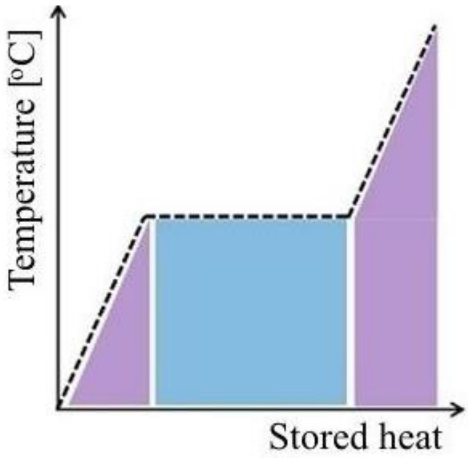
Pebble-bed storage system

A major advantage of a packed-bed storage unit is its high degree of stratification. The pebbles near the entrance are heated, but the temperature of the pebbles near the exit remains unchanged and the exit-air temperature remains very close to the initial bed temperature. As time progresses a temperature front passes through the bed. When the bed is fully charged, its temperature is uniform. A packed bed in a solar heating system does not normally operate with constant inlet temperature. During the day, the variable solar radiation, the ambient temperature, the collector inlet temperature, load requirements, and other time-dependent conditions result in a variable collector outlet temperature.

Latent-Heat or Phase-Change Storage

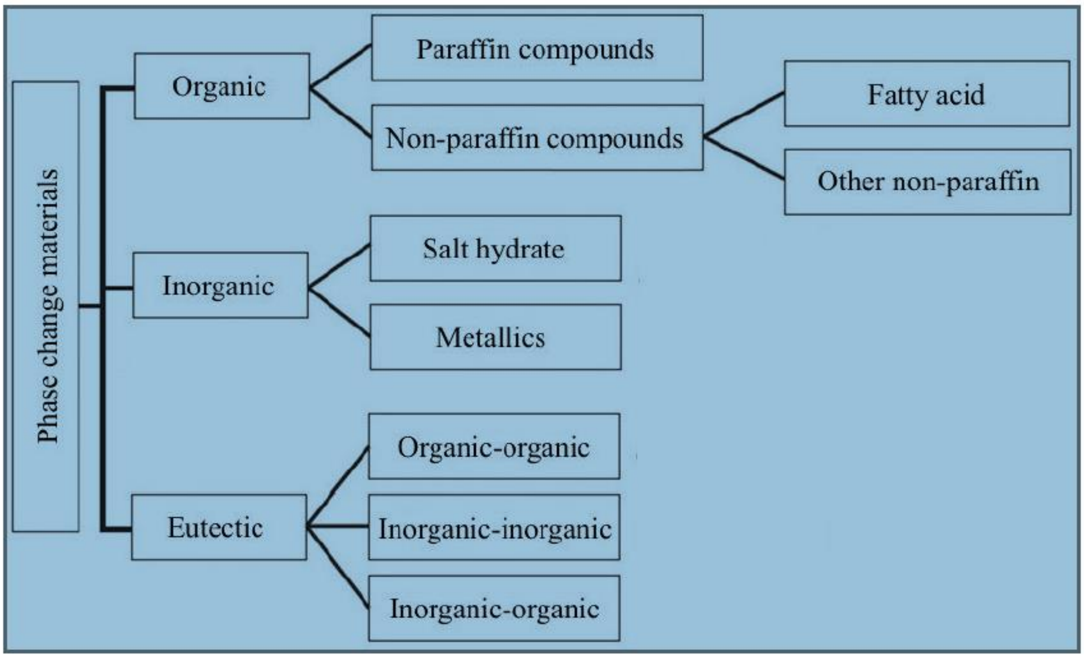
LHS materials are known as PCMs due to their property of releasing or absorbing energy with a change in physical state. The energy storage density increases and hence the volume is reduced, in the case of LHS (Figure2b). The heat is mainly stored in the phase-change process (at a quite constant temperature) and it is directly connected to the latent heat of the substance. The use of an LHS system using PCMs is an effective way of storing thermal energy and has the advantages of high-energy storage density and the isothermal nature of the storage process.

The main advantage of using LHS over SHS is their capacity of storing heat at almost similar temperature range. Initially, these materials act like SHS materials in that the temperature rises linearly with the system enthalpy; however, later, heat is absorbed or released at an almost constant temperature with a change in physical state.



the phase change process takes place in different modes: solid–solid, liquid–gas, and solid-liquid. In the first case, heat is stored by the transition between different kinds of crystallization forms. For liquid-gas systems, latent heat is very high, but there are problems in storage control due to the high volume variations during phase change. The most widespread is the solid-liquid PCMs, which have a limited volume variation during latent heat exchange (generally less than 10%) and a fairly high melting latent heat. Melting processes involve energy densities of 100 kWh/m^3 (e.g., ice) compared to a typical 25 kWh/m^3 for SHS options

Classification of phase change storage



PCM Containment

Containment of PCMs helps contain the material in liquid and solid phases to prevent its possible variation in chemical composition by interaction with its surroundings, to increase its compatibility with other materials in the storage system, to increase its handiness, and to provide a suitable surface for heat transfer. Types of containment studied are bulk storage in tank heat exchangers, macro-encapsulation, and micro-encapsulation. The main characteristic of PCM bulk systems is the need for more extensive heat transfer than that found in non-PCM tanks because the heat storage density of the PCM is higher compared to other storage media. The different approaches extensively used are inserting fins and using high conductivity particles, metal structures, fibbers on the PCM side, direct contact heat exchangers, or the rolling cylinder method

Advantages, Disadvantages, and Selection of PCMs

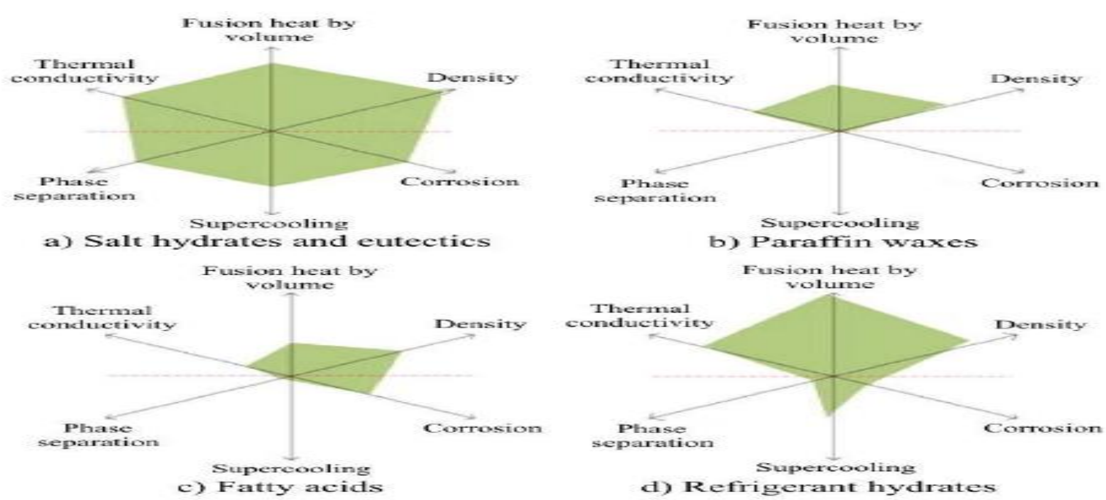
The main advantages of PCM versus water SHSs are

- the possibility of reducing the tank volume for a given amount of energy stored, which can be done only if storage is operated in a very narrow temperature range around the phase-transition temperature, and
- fewer on-off cycles of auxiliary heaters (for plants with storage on the hot side) and chillers (for plants with storage on the cold side).

The main drawbacks of PCM versus water SHSs are

- higher investment costs, and
- higher risks due to leaks of stability and erosion of material encapsulating PCMs.

Thermal properties of various PCMs



Major Environmental Problems

During the past few decades, the risks and reality of environmental degradation have become increasingly apparent. The environmental impact of human activities has grown dramatically due to a combination of factors such as increasing world population, energy consumption, industrial activity, and so on. Throughout the 1970s, most environmental analysis and control instruments concentrated on conventional pollutants such as SO_2, nitrogen oxides (NO_x), particulates, and CO. Recently, environmental concern has extended to the control of micro- or hazardous air pollutants, which are usually toxic chemical substances that are harmful in small doses, as well as globally significant emissions such as CO_2. Despite advances in environmental science, developments in industrial processes and structures have led to new environmental problems such as an increase in the effects of NO_x and volatile organic compound (VOC) emissions. Details on these gaseous and particulate pollutants and their impacts on the environment and human bodies may be found elsewhere (Dincer, 1998). Environmental problems span a continuously growing range of pollutants and hazards and include ecosystem degradation over ever-wider areas.
The major areas of environmental concern may be classified as follows:-

- acid rain
- hazardous air pollutants,
- global warming and climate change,
- stratospheric ozone depletion,
- land use and siting impact,
- water and maritime pollution,
- poor ambient air quality,
- major environmental accidents.
- solid waste disposal, and
- radiation and radioactivity

Among these environmental issues, the most internationally known and most significant ones are usually considered to be acid precipitation, stratospheric ozone depletion, and global climate change potential Solutions to Environmental ProblemsGeneral Solutions
Various potential solutions to the current environmental problems associated with harmful pollutant emissions have recently evolved, including

• use of TES technologies;
• use of renewable energy technologies;
• use of alternative energy forms and sources for transport;
• cogeneration and district heating and cooling;
• energy conservation and increasing the efficiency of energy utilization;
• energy-source switching from fossil fuels to environmentally benign energy forms;
• use of coal-cleaning technologies;
• optimum monitoring and evaluation of energy indicators;
• process change and sectoral modification;
• recycling;
• policy integration;
• material substitution;
• application of carbon and/or fuel taxes;
• acceleration of forestation;
• increasing public awareness of energy-related environmental problems;
• changing lifestyles;
• promoting public transport;
• increased education and training.

Conclusion

There are a number of environmental problems that we face today. These problems span a continuously growing range of pollutants, hazards on the Environment. Energy storage technology is introduced, The working principle of various energy storage technology and classification, Technical status, Advantage and disadvantage and the problem on our environment and their solution of also described.

Reference

1. Sarbu, I., & Sebarchievici, C. (2018). A comprehensive review of thermal energy storage. Sustainability, 10(1), 191.
2. Dinçer, İ., & Rosen, M. A. (2010). Thermal energy storage and environmental impact. Thermal energy storage. Wiley, Hoboken, 191-209.

3. Rohit, A. K., Devi, K. P., & Rangnekar, S. (2017). An overview of energy storage and its importance in the Indian renewable energy sector: Part I–Technologies and Comparison. Journal of Energy Storage, 13, 10-23.
4. Garg HP, Mullick SC, Bhargava AK. Solar thermal energy storage. D.Reidel Publishing Co; 1985.
5. Hasnain, S. M. (1998). Review on sustainable thermal energy storage technologies, Part I: heat storage materials and techniques. Energy conversion and management, 39(11), 1127-1138.
6. Moosavi, Z. M., & Zohoor, H. (2008, November). Improving the capability of solar thermal energy storage by using a hybrid energy storage system. In 2008 IEEE International Conference on Sustainable Energy Technologies (pp. 394-398). IEEE.
7. Kumar, A., & Shukla, S. K. (2015). A review on a thermal energy storage unit for solar thermal power plant application. Energy Procedia, 74, 462-469.
8. Buddhi D, Sawhney RL, Proceedings on thermal energy storage and energy conversion,1994
9. Zalba B., Marin JM, Cabeza L.F, Mehling H, Review on thermal energy storage with phase change: materials, heat transfer analysis and applications, Appl. Therm. Eng. 23 (2003) 251□283.
10. Salaudeen, S. A. (2019). Investigation on the performance and environmental impact of a latent heat thermal energy storage system. Journal of King Saud University-Engineering Sciences, 31(4), 368-374.
11. Hammou, Z. A., & Lacroix, M. (2006). A hybrid thermal energy storage system for managing simultaneously solar and electric energy. Energy Conversion and Management, 47(3), 273-288.