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A REVIEW PAPER ON SOLAR THERMAL ENERGY STORAGE SYSTEM

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ABSTRACT

Solar thermal energy can be stored by three different ways, namely 1) Sensible heat storage (SHS), 2) Latent heat storage (LHS), and 3) Thermo-Chemical storage (TCS). The SHS refers to the energy systems that store thermal energy without phase change. The SHS occurs by adding heat to the storage medium and increasing its temperature. Heat is added from a heat source to the liquid or solid storage medium. Heating of a material that undergoes a phase change (usually melting) is called the LHS. The amount of energy stored in the LHS depends upon the mass and latent heat of the material. In the LHS, the storage operates isothermally at the phase change of the material. Lastly, comparison of storage. Thermo-chemical storage (TCS) using chemical reactions to store and release thermal energy.

KEYWORDS: Thermal energy storage (TES), sensible heat storage (SHS), latent heat storage (LHS)

INTRODUCTION

Today we are face two most pressing challenges addressing our expanding energy needs and reducing our greenhouse gas emissions from the use of fossil fuels. Solar energy offers a promising solution to both challenges because of its abundance and lack of greenhouse gas emissions. However, a transformation from fossil fuels to solar energy requires efficient and cost effective processes to collect, store, and transport our intermittent source of energy.

Developing efficient and inexpensive energy storage devices is as important as developing new sources of energy. The thermal energy storage (TES) can be defined as the temporary storage of thermal energy at high or low temperatures. Energy storage can reduce the time or rate mismatch between energy supply and energy demand, and it plays an important role in energy conservation. Energy storage improves performance of energy systems by smoothing supply and increasing reliability. For example, storage would improve the performance of a power generating plant by load leveling. The higher efficiency would lead to energy conservation and improve cost effectiveness. Some of the renewable energy sources can only provide energy intermittently. Although the sun provides an abundant, clean and safe source of energy, the supply of this energy is periodic following yearly and diurnal cycles; it is intermittent, often unpredictable and diffused. Its density is low compared with the energy flux densities found in conventional fossil energy devices like coal or oil-fired furnaces. The demand for energy, on the other hand, is also unsteady following yearly and diurnal cycles for both industrial and personal needs. Therefore the need for the storage of solar energy cannot be avoided. Otherwise, solar energy has to be used as soon as it is received.

Thermal energy storage (TES) includes a number of different technologies. Thermal energy can be stored at temperatures from -40°C to more than 400°C as sensible heat, latent heat and chemical energy (i.e. thermo-chemical energy storage) using chemical reactions. Thermal energy storage in the form of sensible heat is based on the specific heat of a storage medium, which is usually kept in storage tanks with high thermal insulation. 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. However, TES systems based on sensible heat storage offer a storage capacity that is limited by the specific heat of the storage medium. Phase change materials (PCMs) can offer a higher storage capacity that is associated with the latent heat of the phase change. PCMs also enable a target-oriented discharging temperature that is set by the constant temperature of the phase change. Thermo-chemical storage (TCS) can offer even higher storage capacities. Thermo-chemical reactions (e.g. *adsorption* or the adhesion of a substance to the surface of another solid or liquid) can be used to accumulate and discharge heat and cold on demand (also regulating humidity) in a variety of applications using different chemical reactants. At present, TES systems based on sensible heat are commercially available while TCS and PCM-based storage systems are mostly under development and demonstration.

METHODS OF THERMAL ENERGY STORAGE

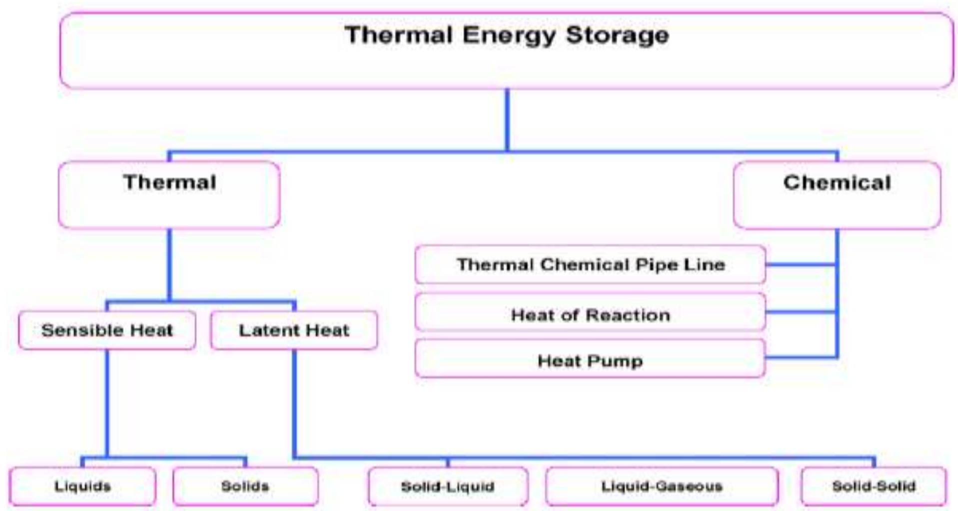

Fig No 1 Diffrent types of thermal storage of solar energy

Sensible heat storage.

Heating a liquid or a solid, without changing phase: This method is called sensible heat storage. The amount of energy stored depends on the temperature change of the material.

$$E = m\int_{T1}^{T2} CpdT \quad (1)$$

Where

m is the mass of material used for heat store

C_p the specific heat of mass at constant pressure.

T_1 and T_2 represent the lower and upper temperature levels between which the storage operates.

$(T_2 - T_1)$ is referred to as the temperature swing.

a) Liquid Storage Media

With its highest specific heat water is the most commonly used medium in a sensible heat storage system. Most solar water heating and space-heating systems use hot water storage tanks located either inside or outside the buildings or underground. Water storage tanks are made from a variety of materials like steel, concrete and fiberglass. The tanks are suitably insulated with glass wool, mineral wool or polyurethane. If the water is at atmospheric pressure, the temperature is limited to 100°C. It is possible to store water at temperature a little above 100°C by using pressurized tanks. Other liquid storage media are tabulated below

Table No.2 Properties of liquid media

storage Medium	Fluid Type	Temp Range.(=ºC)	Density Kg/m^3	Heat Capacity (J/kg.K)	Thermal Conductivity(W/m.K)
Water	-	0 to 100	1000	4190	0.63 at 38°C
Dowtherms	Oil	12 to 260	867	2200	0.112 at 260°C
Sodium	Liquid salt	100 to 760	960	1300	67.5
Ethanol	Organic liquid	Up to 78	790	2400	-

b) Solid Storage Media

Energy can be stored in rocks or pebbles packed in insulated vessels. This type of storage is used very often for temperatures up to100°C in conjunction with solar air heaters. It is simple in design and relatively inexpensive. Typically, the characteristic size of the pieces of rock used varies from 1 to 5 cm. An approximate rule of thumb for sizing is to use 300 to 500 kg of rock per square meter of collector area for space heating applications. Rock or pebble-bed storages can also be used for much higher temperatures up to 1000°C.Magnesium oxide (magnesia), aluminum oxide (alumina) and silicone oxide are refractory materials, and they are also suitable for high-temperature sensible heat storage. Bricks made of magnesia have been used in many countries for many years for storing heat. Below, the properties of solid media storage are listed

Table No.2 Properties of solid media storage

Medium	Density (kg/m^3)	Specific Heat (J/kg.K)	Heat Capacity ρcx10^{-6} (J/m^3.K)	Thermal Conductivity (W/m.K)	Thermal Diffusivity α = k/ρc 10^6 (m^2/s)
Aluminum	2707	896	2.4255	204 at 20°C	84.100
Brick	1698	840	1.4263	0.69 at 29°C	0.484
Stone, granite	2640	820	2.1648	1.73 to 3.98	0.799-1.840
Stone, limestone	2500	900	2.2500	1.26 to1.33	0.560-0.591

LATENT HEAT ENERGY STORAGE

Sensible heat storage is relatively inexpensive, but its drawbacks are its low energy density and its variable discharging temperature. These issues can be overcome by phase change materials (PCM)-based TES, which enables higher storage capacities and target oriented discharging temperatures. PCM is the heart of the LHS system

Working of a PCM system

Initially, the PCM is in solid state. As the environmental temperature rises, it absorbs energy in the form of sensible heat. When ambient temperature reaches the melting point of the PCM, it absorbs large amounts of heat at an almost constant temperature. This continues until all the material is transformed to the liquid phase. In this way, heat is stored in a PCM and the temperature is maintained at an optimum level. When the environmental temperature around the liquid PCM falls, it solidifies again, releasing its stored latent heat. Thus, the managed temperature again remains consistent.

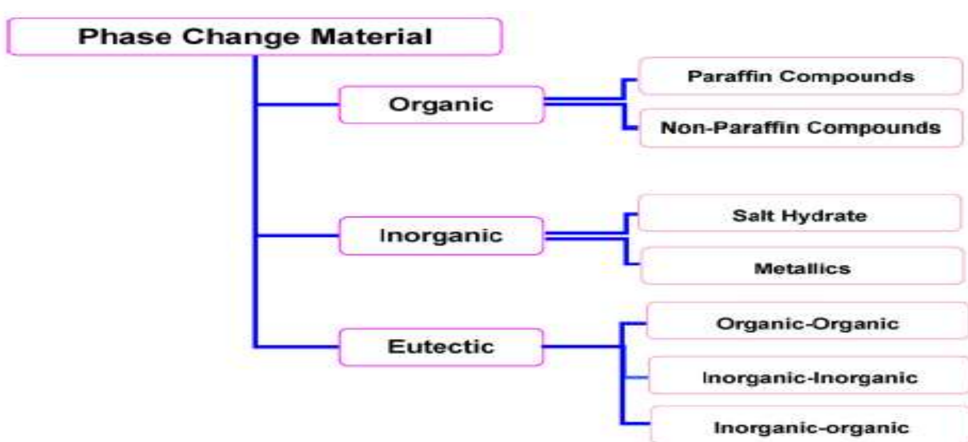

Fig No 2 Classification of Phase change materials

Organic phase change materials

a) Paraffin's

Paraffin wax consists of a mixture of mostly straight chain n-alkanes CH_3–(CH_2)–CH_3. The crystallization of the (CH_3)- chain release a large amount of latent heat. Both the melting point and latent heat of fusion increase with chain length. Paraffin qualifies as heat of fusion storage materials due to their availability in a large temperature range. Due to cost consideration, however, only technical grade paraffin's may be used as PCMs in latent heat storage systems. Paraffin is safe, reliable, predictable, less expensive and non-corrosive. They are chemically inert and stable below 500 ^{0}C, show little volume changes on melting and have low vapor pressure in the melt form. For these properties of the paraffin's, system-using paraffin's usually have very long freeze–melt cycle.

b) Non-paraffin's

The non-paraffin organic are the most numerous of the phase change materials with highly varied properties. Each of these materials will have its own properties unlike the paraffin's, which have very similar properties. This is the largest category of candidate's materials for phase change storage. Some of the features of these organic materials are as follows: (i) high heat of fusion, (ii) inflammability, (iii) low thermal conductivity, (iv) low flash points, (v) varying level of toxicity, and (vi) instability at high temperatures. Fatty acids have high heat of fusion values comparable to that of paraffin's. Fatty acids also show reproducible melting and freezing behavior and freeze with no super cooling. Their major drawback, however, is their cost, which are 2–2.5 times greater than that of technical grade paraffin's. They are also mild corrosive. Some fatty acids of interest to low temperature latent heat thermal energy storage

c) Eutectics

A eutectic is a minimum-melting composition of two or more components, each of which melts and freeze congruently forming a mixture of the component crystals during crystallization . Eutectic nearly always melts and freezes without segregation since they freeze to an intimate mixture of crystals, leaving little opportunity for the components to separate. On melting both components liquefy simultaneously, again with separation unlikely.

THERMAL ENERGY STORAGE VIA CHEMICAL REACTIONS –

High energy can be achieved using chemical reactions. Energy may be stored in systems composed of one or more chemical compounds that absorb or release energy through chemical reactions. There are many forms in which energy can be stored through chemical reactions. Chemical storage involves an endothermic reversible reaction, which can be reversed when required to release heat. The chemical produced can often be stored cold (without losses) and can often be transported easily. For storage of thermal energy in chemical energy, one prefers reversible chemical reactions. During charging the supplied heat for a chemical reaction to be considered for energy storage, the following conditions should be met:

- The reaction should be run near equilibrium, i.e. reversible.
- The reactant, with or without addition of a photosensitizer, should be able to use as much of the solar spectrum in the terrestrial atmosphere as possible.
- The energy stored in the bond energy should be large enough.
- The reactants should be cheap.

Table No.3 Various Thermo Chemical Storage options

Reaction		**Temp. °C**	**En. density, kJ/kg**
Methane steam reforming	$CH_4+H_2O=CO+3H_2$	480-1195	6053
Ammonia dissociation	$2NH_3=N_2+3H_2$	400-500	3940
Thermal dehydrogenation of metal hydrides	$MgH_2=Mg+H_2$	250-500	3079 heat stor. 9000 H2 stor.
Dehydration of metal hydroxides	$CA(OH)_2=CAO+H_2O$	402-572	1415
Catalytic dissociation	$SO_3=SO_2+ ½O_2$	520-960	1235

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Table No.4 Comparison of Different Storage Techniques

Technical Performance	**SHS**	**LHS**	**TCS**
Cost	Inexpensive	Expensive	Expensive
Specific Heat	High	Medium	High
Required heat exchanger	Simple	Complex	Complex
Required Space	Large	Small	Large
Market Share	0.25	Negligible	N/A
Environmental Impact	Negligible		

CONCLUSION

With the declining supply of conventional sources of energy, the need and demand for the utilization of renewable sources has increased. With developments in TES technology on almost a day to- day basis, this technology is sure to become a prominent thermal storage technique in the near future. This review paper is focused on the available thermal energy storage technology. Those technologies is very beneficial for the humans and as well as for the energy conservation. This paper presents the current research in this particular field, with the main focus being on the assessment of the thermal properties of various PCMs.

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