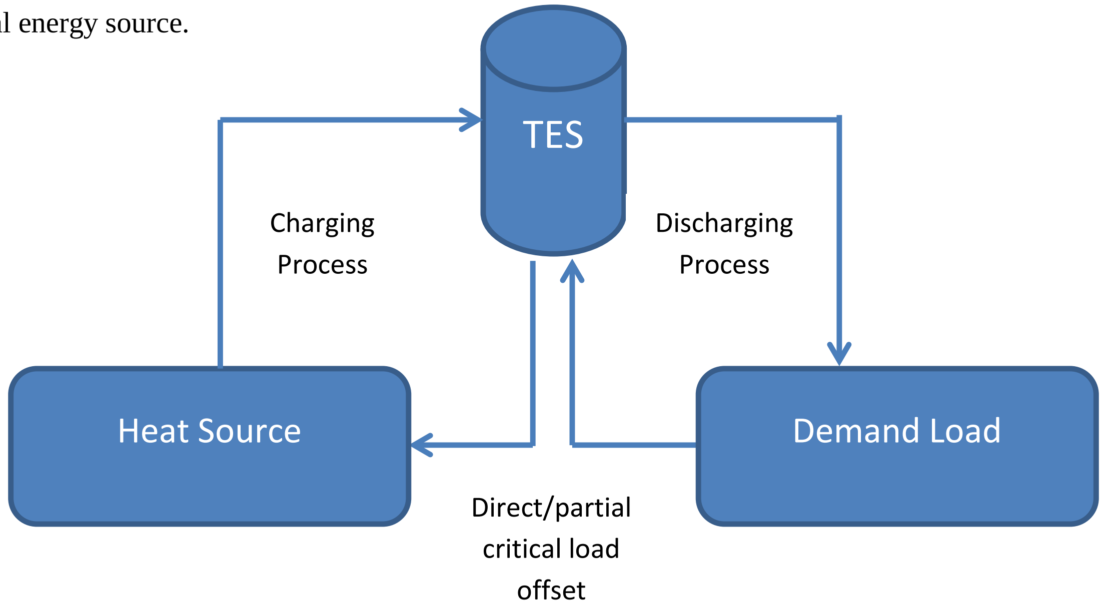
MODELLING AND NUMERICAL SIMULATION PHASE CHANGE MATERIAL THERMAL ENERGY STORAGE

INTRODUCTION: Several techniques have been provided for fostering energy storage technologies, either electrical energy or thermal energy storage technologies. The storage of electrical energy can be performed either directly or indirectly through electrical input and output. On the other hand, thermal energy storage uses the sensible heat or latent heat or thermochemical reaction capabilities of materials to store and retrieve heat energy on demand.

Thermal energy storage (TES), or thermal storage, is an efficient available technology that caters to energy demand through energy redistribution. In thermal energy storage systems, energy in the form of heat or cold can be placed in a storage medium for a particular duration and can be retrieved from the same location for later usage. This is the baseline concept of thermal energy systems (TES), wherein the term *thermal* refers to either heat or cold, depending on the energy interactions between the storage medium and the energy source. The simple schematic representation, shown in figure below, elaborates the general operational mode of the TES system being integrated with the available thermal energy source.



Types of TES technologies:

Three major physical principles by which the heat energy the heat or cold energy can be stored are:

- **Sensible Thermal Energy Storage**: In such systems, heat exchanged by the system changes the temperature of the system, implying that heat absorption leads to an increase in temperature and heat dissipation leads to a decrease in temperature. Specific heat capacity of the material typically decides its utility as the storage material in such systems.
- **Thermochemical Thermal Energy Storage**: High energy density TES systems can also be achieved using chemical reactions. Many thermo-chemical reactions like adsorption can be used to store heat, and control humidity. The high storage capacity of sorption processes also allows thermal energy transportation.

- **Latent Thermal Energy Storage:** These systems are based on the proposition of maintenance of constant temperature in the system as heat is heat is supplied to the storage material at its melting temperature. Latent heat storage systems are more attractive than sensible heat storage systems because of their high storage density with smaller temperature rise.

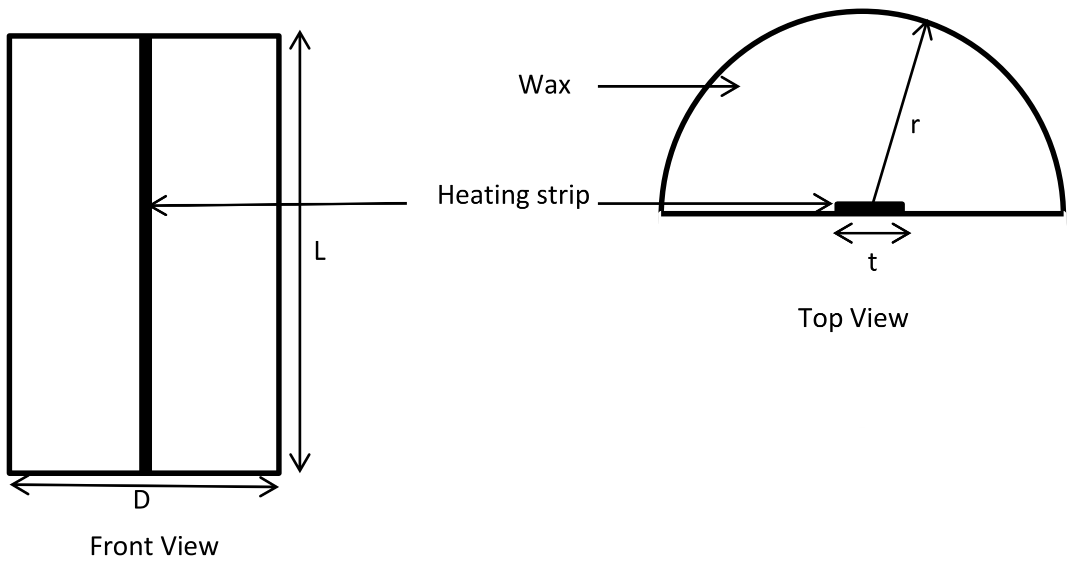
  The LTES methods that are primarily intended for energy storage are categorized into two types, ice-thermal energy storage (ITES) and Phase Change Material (PCM) thermal energy storage (PCM-TES). ITES refers to the use of ice in the form of crystals or slurries as the heat storage material, whereas in PCM-TES, the functional heat storage material constitutes a variety of chemical species classified under the organic, inorganic and eutectic mixtures. PCMs are preferred over the ice-water systems largely because they have better thermo physical properties, which exhibit good phase change characteristics during charging and discharging cycles, have higher energy storage densities and have the ability to store heat at the temperature at which phase transition of PCM takes place. Phase change materials offer higher storage capacity and storage efficiencies (75-90%).

AIM: The aim of this work is to model the PCM-TES and numerically simulate the system using OpenFOAM, to get a better understanding of the physical system and compare the numerical results with existing experimental results.

PROBLEM DEFINITION:

Physical set up: Wax is filled in a semi-cylinder stainless steel container, which covers all surfaces except the front face. The front face is covered by a transparent sheet. All the surfaces are considered to be perfectly insulated. A wax reservoir ensures no change in density. Heat is supplied by a heating strip which as a line source of constant heat flux as input to the solid wax.

The temperature profiles at different time are to be compared to that obtained by experiment. The geometrical set up is shown below:



Governing Differential Equations:

$$\frac{\partial \rho}{\partial t} + \vec{\nabla} \cdot (\rho \vec{u}) = 0$$

$$\frac{\partial (\rho \vec{u})}{\partial t} + \vec{\nabla} \cdot (\rho \vec{u}\vec{u}) = -\vec{\nabla} p + \vec{\nabla} \cdot (\mu \vec{\nabla} \vec{u}) + S_u$$

$$\frac{\partial (\rho C_p T)}{\partial t} + \vec{\nabla} \cdot (\rho \vec{u} C_p T) = \vec{\nabla} \cdot (k \vec{\nabla} T) + S_T$$

where

$$S_u = S_{buoyancy} + S_d$$
$$= \rho g \beta (T - T_{ref}) + A\vec{u}$$
$$where$$
$$A = -\frac{DC_l (1-\alpha)^2}{\alpha^3 + DC_s}$$
$$where$$
$$\alpha = 1 (liquid)$$
$$= 0 (solid)$$
$$S_T = -\left[\frac{\partial}{\partial t} \left(\rho \Delta H \right) + \nabla \cdot \left(\rho \vec{u} \Delta H \right) \right]$$

Boundary Conditions:	$-k\nabla T = q_{strip}$	r = 0
	$k\nabla T = 0$	All surfaces

Initial condition: T = Ambient Temperature

REFERENCES:

1. Saraswat, A (2015). *Phase Change Materials (PCM) Storage: Experimental Investigation and Use of Passive Heat Devices (M.tech Dissertation).* IIT Kanpur.
2. Galione, P. A (2014). *Numerical simulation of thermal storage systems. Emphasis on latent energy storage using phase change materials (PCM) (Doctoral Dissertation).* Universitat Politècnica de Catalunya.