High-Temperature Latent Heat Storage

Storage Principle

Latent heat thermal energy storage (LHTES) systems exploit melting and solidification phenomena of a phase change material (PCM) to absorb or release heat at a nearly constant temperature, as shown in Fig. 1. PCMs are particularly attractive due to high-energy storage density and small temperature variation in the storage and retrieval processes.

LHTES can be broadly classified into two categories of low temperature (up to 100°C) and high temperature (HT-LHTES, above 100°C), with the latter being described here. Depending on working temperature range and type of application, the materials for HT-LHTES can be sugar alcohols, metals and their alloys, or salts [1].

Different device designs and system configurations can be adopted for using the PCMs depending on the chemical and physical compatibility of the storage materials with heat transfer medium and containment, and thermal conductivity and volume change during phase transition of the storage materials. Fig. 2 shows some examples of device designs.

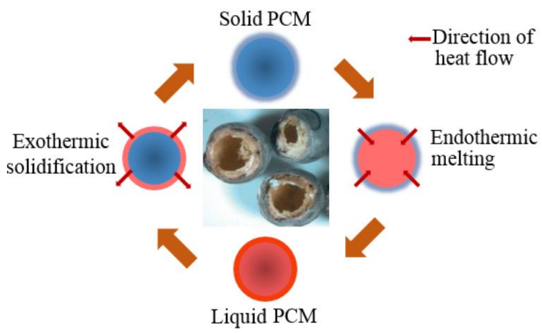
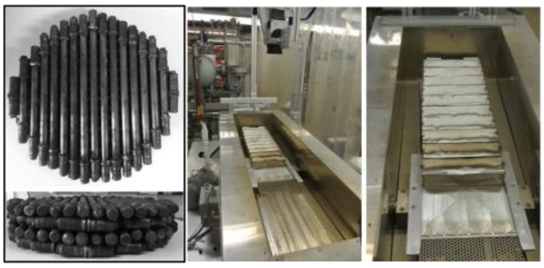


Figure 2. PCM working concept (LHTES) with 5 mm high-temperature PCM capsule with voids shown in the centre [1].



(a) (b)

Figure 2. HT-LHTES (a) encapsulated PCM [2] and (b) lab-scale testing device [2].

Technical Characteristics

Power of a single typical device (MW_{th}): 0.7- 6 [3,4]
Typical size of a single device (MWh): 0.01-10 [3]
Energy density (kWh/m³): 90-100 [3]
Typical operation mode: charge 4-10 hours; discharge 12-24 hours [7][8]
Response time (min.): 2-8 [4]
Technical lifetime (y): 10000 cycles [4]
Temperature range (°C): 100-1000[3]
Cost (€/kWh)[5]: 20-80 [3]
Efficiency (%): 90-98 [4]

Maturity

Installation costs (€/kWh)[1]: 20- 80 [4][8]
Technology readiness level: 5-8 [3]

Challenges in development

- Thermal and chemical stability at high temperatures [6]
- Mechanical stability at high temperatures
- Chemical compatibility between PCM and other components
- Cost-effective PCMs with melting temperature between 300 and 600°C

Potential of technology

- Balancing heat demand and supply for domestic, industrial and commercial applications
- Power-to-Heat applications for grid stabilisation
- Renewable heat and electrification of heat
- Waste heat utilisation

Barriers

- High component costs
- Low TRL for most HT-LHTES storage systems
- HT-PCM material availability with different melting ranges
- High cost of PCMs for some temperature ranges

[5] Projected costs for mature HT-LHTES technology.

Common Applications

- Industrial waste heat recovery for an increased efficiency and a reduced energy consumption.
- Decoupling of power and heat in cogeneration plants.
- Thermal management of thermally driven processes.
- Storage of renewable heat to facilitate a temporal separation from energy production. (Fig. 3).
- Utilization of Power-to-Heat concepts for flexible supply and/or grid stabilisation.
- LHS integration in subcritical steam cycles.

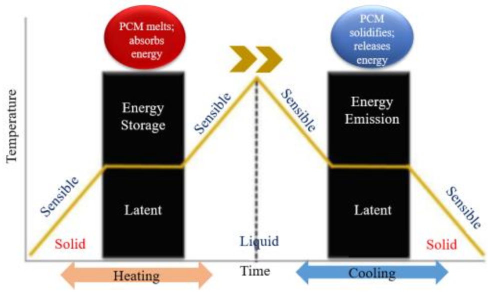


Figure 3. PCM heating-cooling cycles used in applications.

Example Applications

1. Co-generation plants

In co-generation plants, power and heat are simultaneously generated from the same fuel. In such plants, a steam generator is used to produce superheated steam for power generation, whereas heat is stored in HT-LHTES for back-up and peak shaving (Fig. 4).

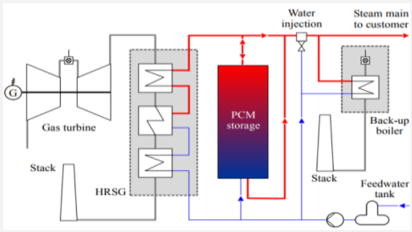


Figure 4. LTES integration in a Co-gen plant [4].

2. Concentrating Solar Power (CSP) plants

Integration of HT-LHTES with CSP offers dispatchable power, increases the share of solar electricity and reduces levelized cost of energy (Fig. 5) [7].

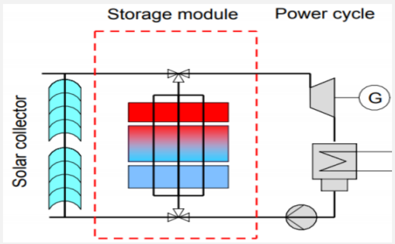


Figure 5. LHTES storage integrated with CSP [7].

3. Direct steam generation processes

Integration of HT-LHTES with direct steam generation processes ensures heat input at nearly constant temperature. Figure 6 shows a 100kWth module with inorganic PCM coupled with a solar-driven direct steam generation process

Figure 6. 100 kW, 220°C storage module [4].

4. Power-to-Heat

A system with a heating power of 6 MW and a total heat storage capacity of 36 MWh was designed and built in 2016 to provide space heating for 57,000 m^2 (Fig. 7). The system takes curtailed wind power (10kV), turning the power to heat and store the heat in high temperature composite PCM at ~700 °C. The overall thermal efficiency is >~95 % [8].

Figure 7. World's first composite PCM (700°C) plant: capacity 6 MW/35 MWh [8].

References

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