PCM solutions for energy storage

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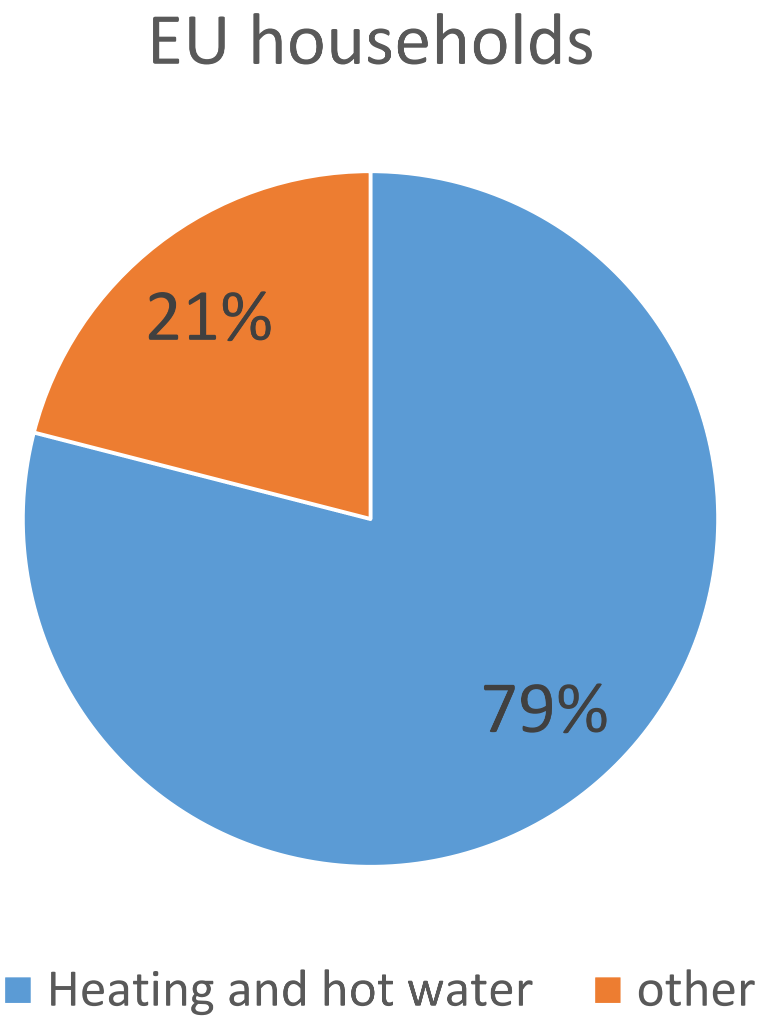
Background

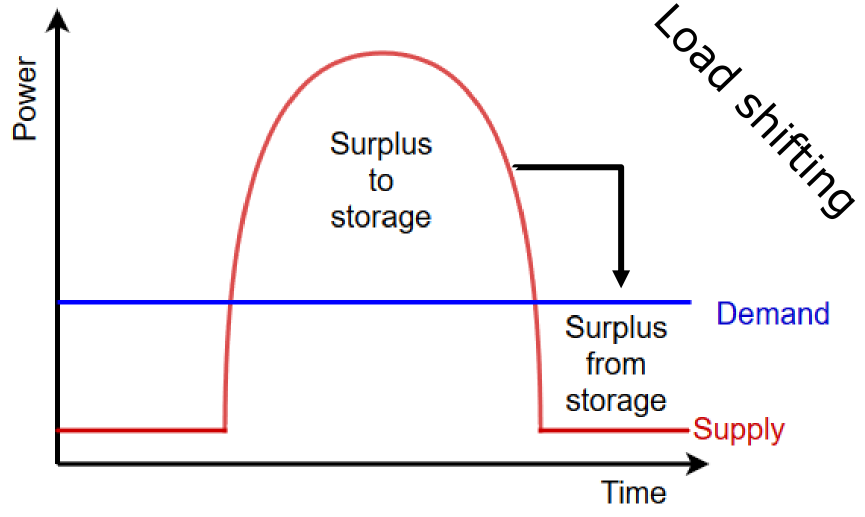
- Building sector
- Thermal energy storage



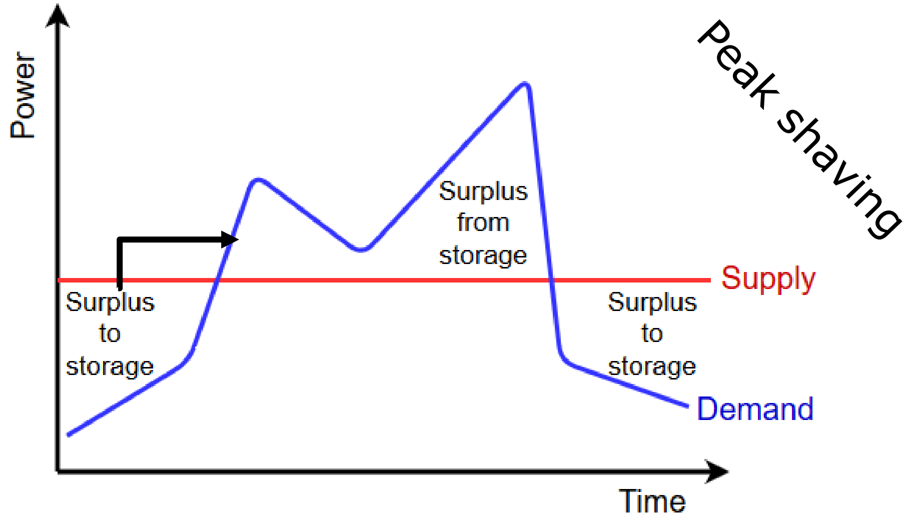
Source: https://ec.europa.eu/energy/en/topics/energy-efficiency/heating-and-cooling

Matching supply and demand

Fluctuating source
Stable demand



Stable source
Fluctuating demand

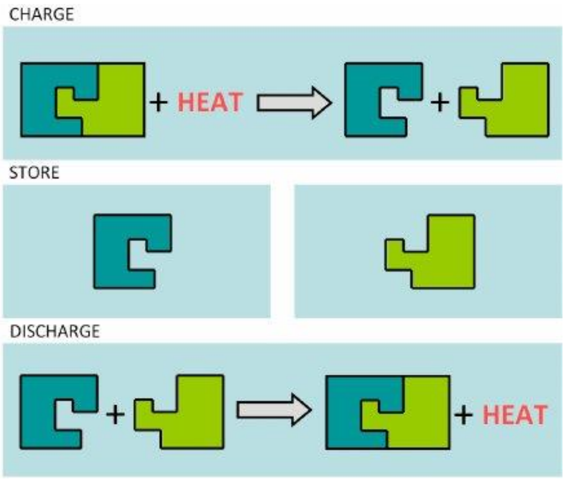


Thermal Energy Storage Technologies

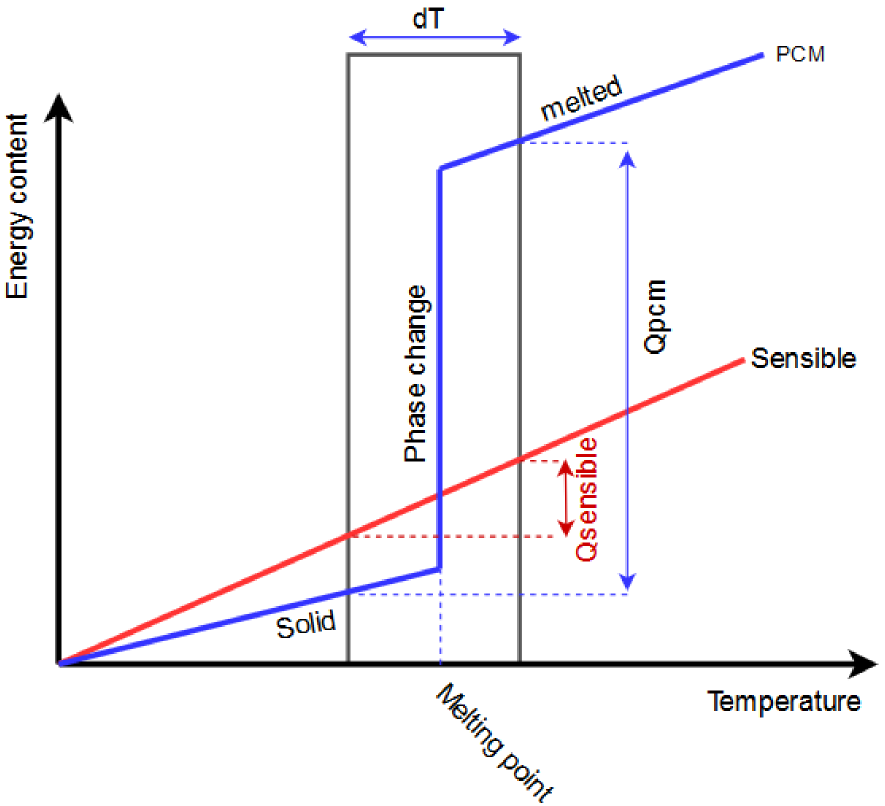
- Sensible heat
  - Water
  - Concrete/bricks
  - soil

- **Latent heat of fusion storage**
  - Phase change (solid/liquid)

- Thermochemical storage



Principle of heat storage in PCM



Brick

Specific heat : 0.9 kJ/kgK

Water (0 ºC)

Specific heat (liquid) 4.18 kJ/kgK

Latent heat of fusion: 334 kJ/kg

Sodium acetate trihydrate (58 ºC)

Specific heat (liquid) 3.1 kJ/kgK

Specific heat (solid) 2.2 kJ/kgK

Latent heat of fusion: 265 kJ/kg

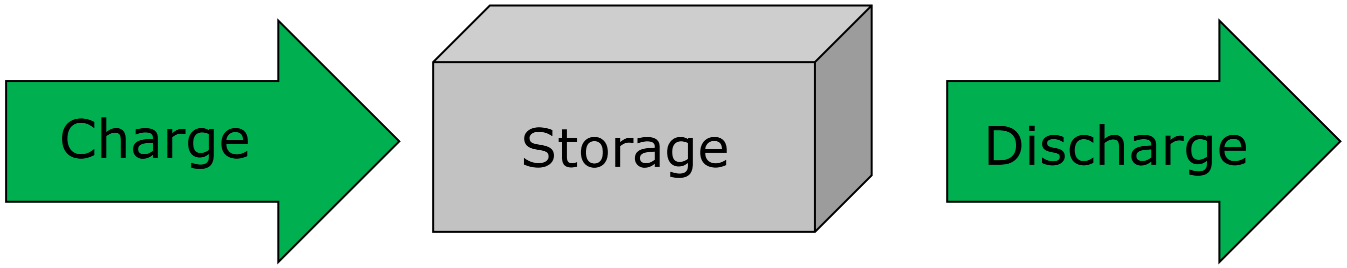
Coconut oil (24 ºC)

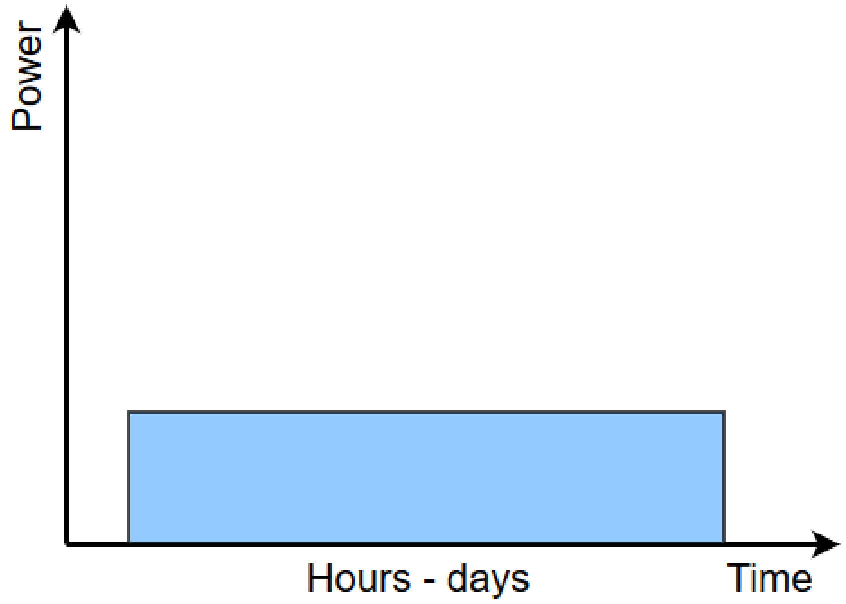
Specific heat (liquid) 2.3 kJ/kgK

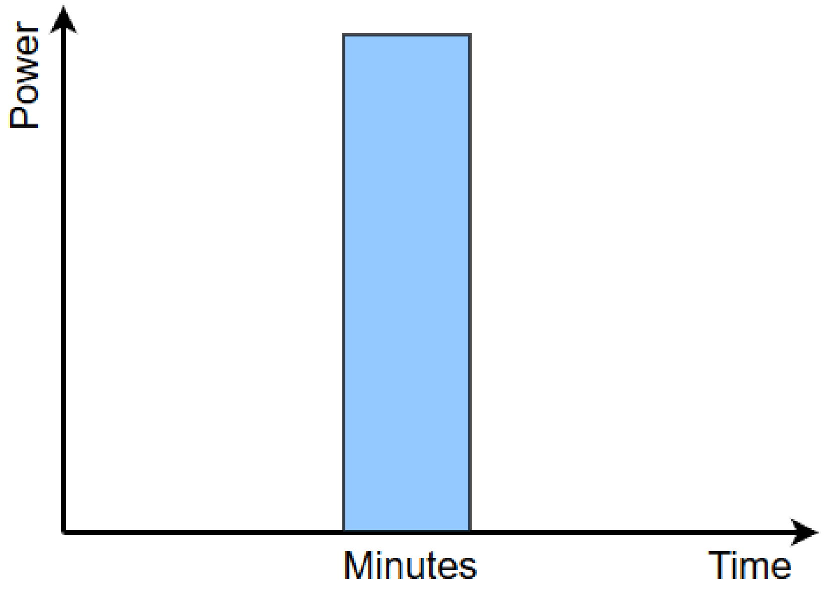
Specific heat (solid) 3.2 kJ/kgK

Latent heat of fusion: 110 kJ/kg

Properties of an energy storage system







- Storage capacity (kWh/kg, kWh/m³)
- Charge / discharge power (W/kg, W/m³)
- Storage efficiency (%)
- Storage period (minutes, days)
- Cost (DKK/kWh)
- Competing technologies

Phase Change Materials

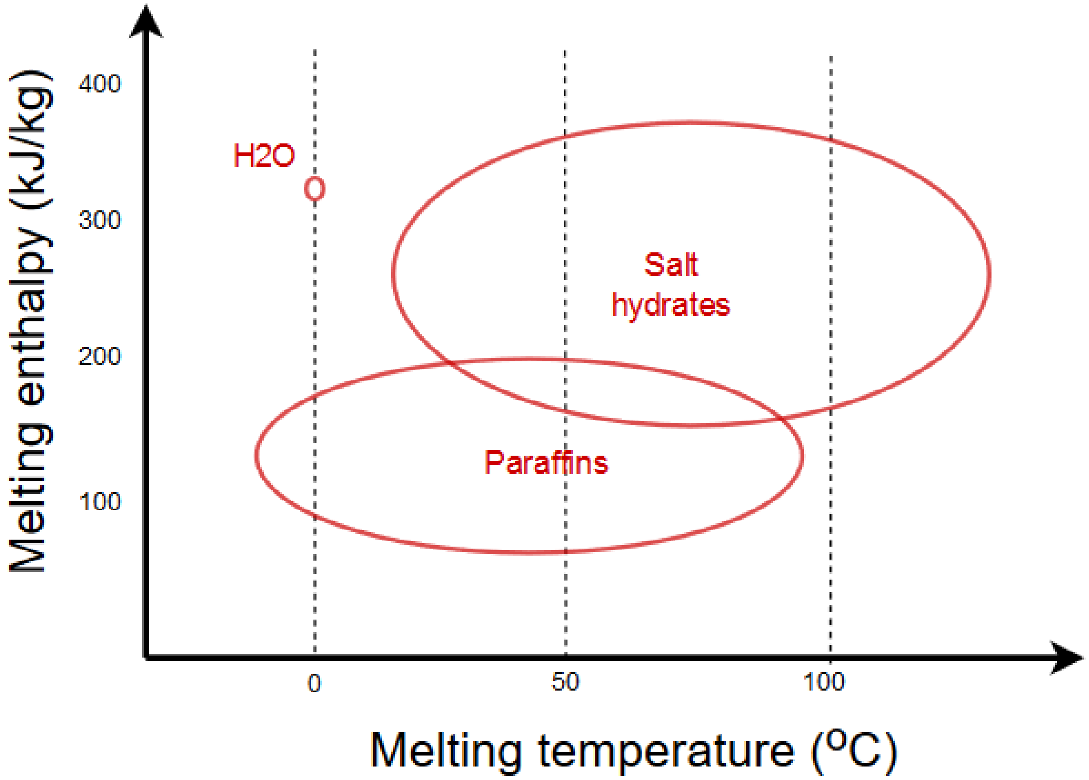


Table 1
Comparison of organic and inorganic materials for heat storage [4,8].

	Organic	Inorganic
Advantages	No corrosives	Greater phase change enthalpy
	Low or none subcooling	
	Chemical and thermal stability	
Disadvantages	Lower phase change enthalpy	Subcooling
	Low thermal conductivity	Corrosion
	Flammability	Phase separation
		Phase segregation, lack of thermal stability

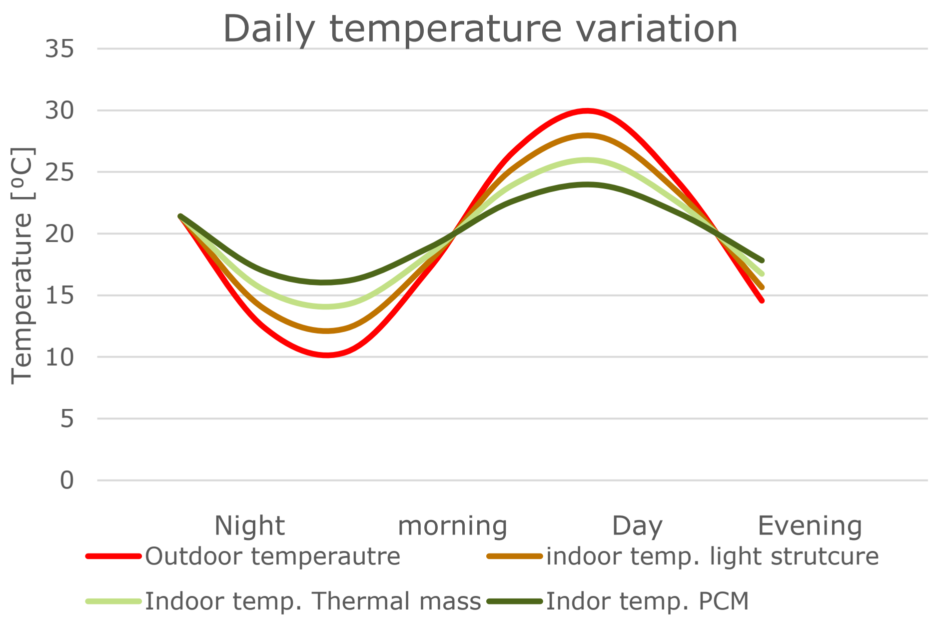
Source: de Gracia, A., & Cabeza, L. F. (2017). Numerical simulation of a PCM packed bed system: A review. Renewable and Sustainable Energy Reviews, 69, 1055–1063. https://doi.org/10.1016/j.rser.2016.09.09

Encapsulated PCM

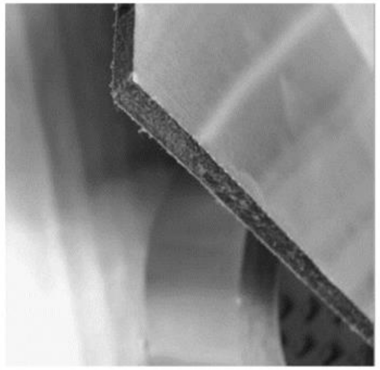
Source: https://www.global-e-systems.com/en/products/gaia-pcm-energy-storage-ball/

product	melting area	heat storage capacity ø
RT - 9 HC	-9°C	250 kJ/kg
RT - 4	-4°C	180 kJ/kg
RT 0	0°C	175 kJ/kg
RT 2 HC	2°C	200 kJ/kg
RT 3 HC_1	3°C	190 kJ/kg
RT 4	4°C	175 kJ/kg
RT 5	5°C	180 kJ/kg
RT 5 HC	5°C	250 kJ/kg
RT 8	8°C	175 kJ/kg
RT 8 HC	8°C	190 kJ/kg
RT 9	9°C	175 kJ/kg
RT 10	10°C	160 kJ/kg
RT 10 HC	10°C	200 kJ/kg
RT 11 HC	11°C	200 kJ/kg
RT 12	12°C	155 kJ/kg
RT 15	15°C	155 kJ/kg
RT 18 HC	18°C	260 kJ/kg
RT 21	21°C	155 kJ/kg
RT 21 HC	21°C	190 kJ/kg
RT 22 HC	22°C	190 kJ/kg
RT 24	24°C	160 kJ/kg
RT 25	25°C	170 kJ/kg
RT 25 HC	25°C	230 kJ/kg
RT 26	26°C	180 kJ/kg
RT 28 HC	28°C	250 kJ/kg
RT 31	31°C	165 kJ/kg
RT 31	31°C	165 kJ/kg
RT 35	35°C	160 kJ/kg
RT 42	42°C	165 kJ/kg
RT 35 HC	35°C	240 kJ/kg
RT 44 HC	44°C	250 kJ/kg
RT 47	47°C	165 kJ/kg
RT 50	50°C	160 kJ/kg
RT 54 HC	54°C	200 kJ/kg
RT 55	55°C	170 kJ/kg
RT 60	60°C	160 kJ/kg
RT62HC	62°C	230 kJ/kg
RT 64 HC	64°C	250 kJ/kg
RT 65	65°C	150 kJ/kg
RT69HC	69°C	230 kJ/kg
RT 70 HC	70°C	260 kJ/kg
RT 82	82°C	170 kJ/kg
RT 80 HC	78°C	220 kJ/kg
RT 90 HC	90°C	170 kJ/kg
RT100	~100°C	120 kJ/kg
RT100HC	100°C	180 kJ/kg

Passive PCM energy storage in buildings

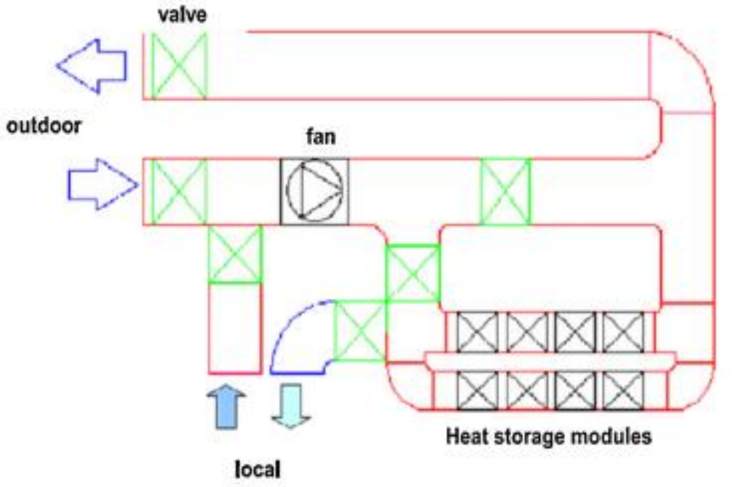


- Increase indoor thermal comfort (air temperature peak reduction, decrease of daily temperature swing)
- Improve buildings envelope performance and increase system efficiency (enhancing the thermal capacity)
- Decrease the conditioning power needed (reduction of the heating and cooling peak loads)
- Reduce energy consumption
- Take advantage of off-peak energy savings
- Take advantage of passive solar gain
- Save money during the operational phase
- Contribute for the reduction of CO2 emissions associated to heating and cooling

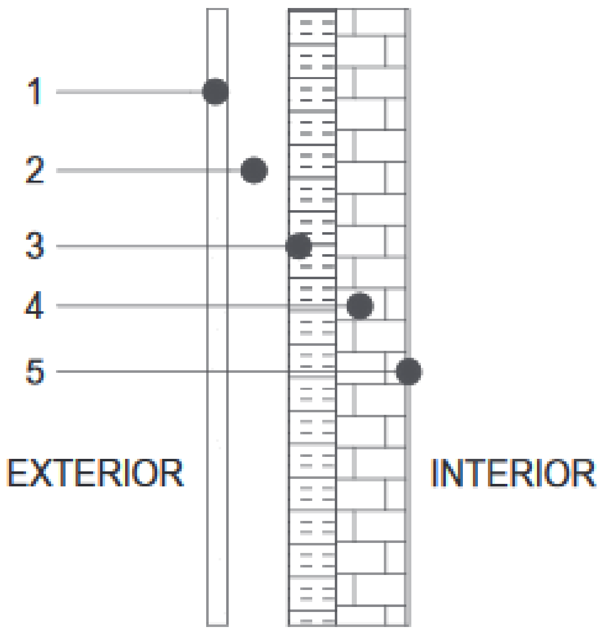


Soares, N., Costa, J. J., Gaspar, A. R., & Santos, P. (2013). Review of passive PCM latent heat thermal energy storage systems towards buildings' energy efficiency. Energy and Buildings, 59, 82–103. https://doi.org/10.1016/j.enbuild.2012.12.042

Active systems - Ventilation



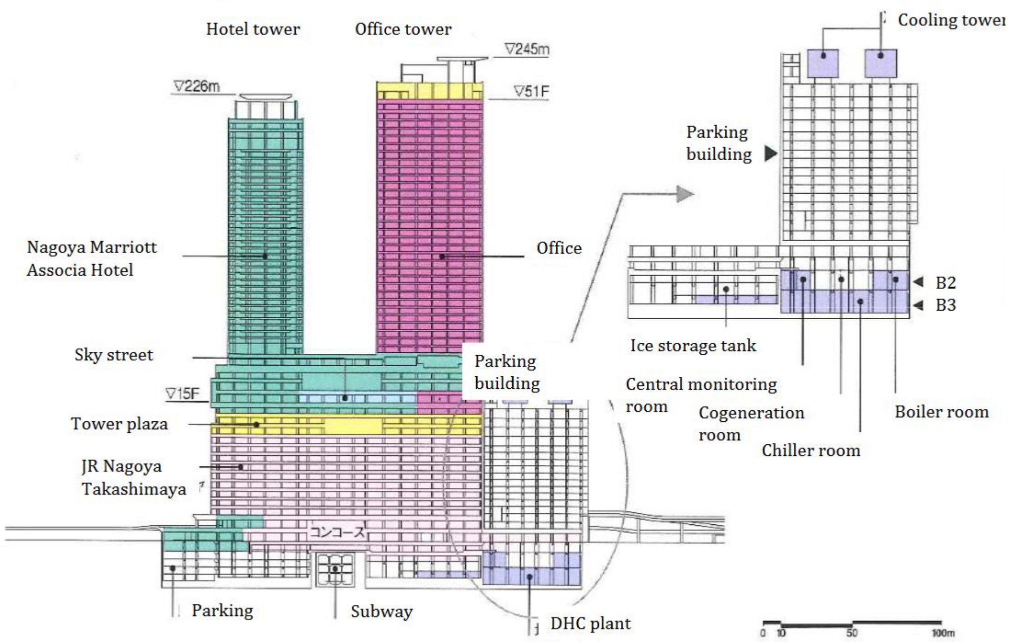
E. Osterman et al. / Energy and Bu

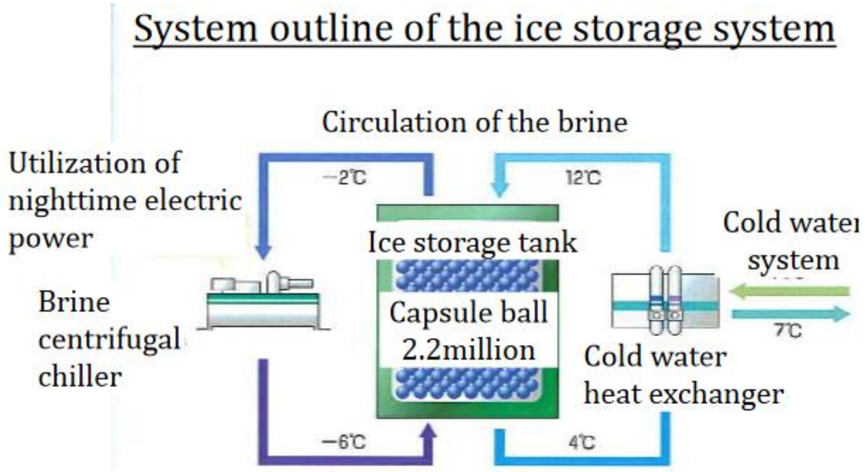


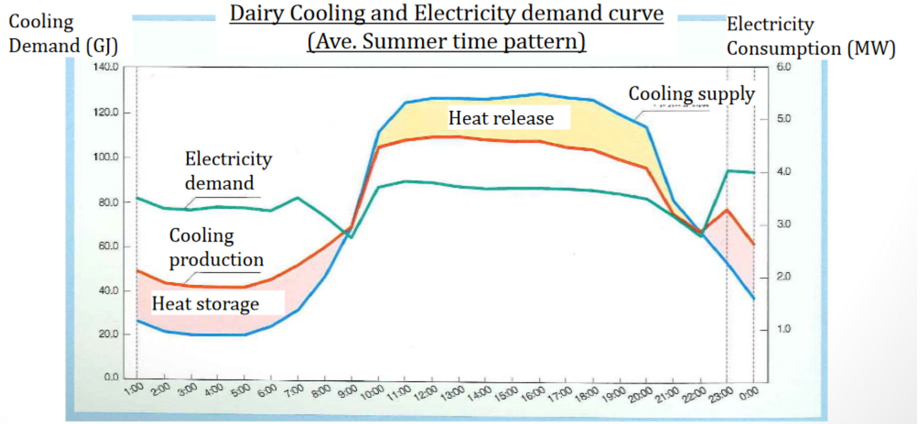
Layer Id	Description	Thickness (mm)
1	External sheet containing PCM	20
2	Ventilated air gap	60
3	Extruded polyestyrene insulation	50
4	Brickwork inner wall	70
5	Gypsum plasterboard	2

G. Diarce et al. / Applied Energy 109 (2013) 530–537

Cold storage – Ice storage







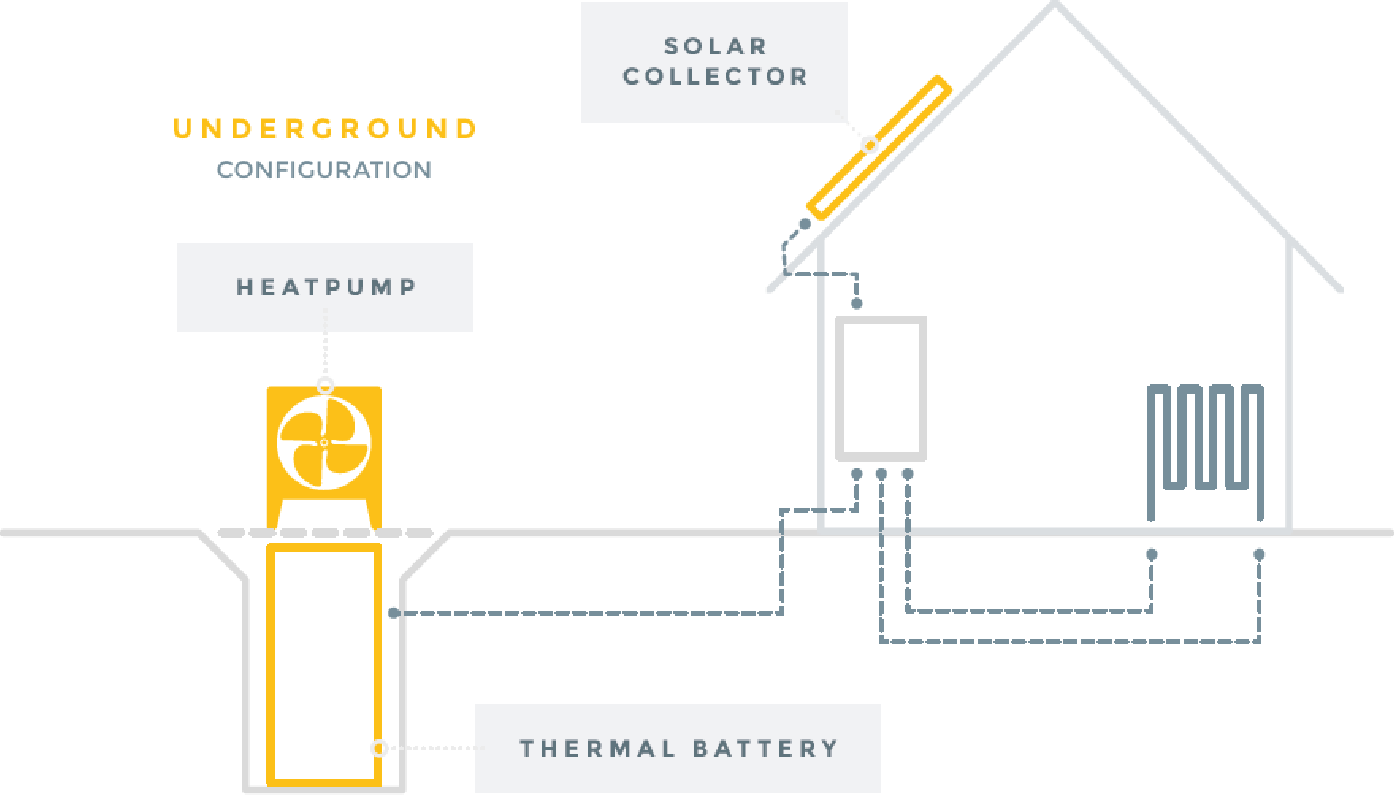
Active system - Heat storage

SUNTHERM

https://www.suntherm.dk/

1. Heat pump
2. Heat storage
3. Central heating unit
4. Smart control

SUNTHERM heat of fusion storage:
70 cm cylinder design
Content: 350 kg salt hydrate
Heat content: 25 kWh

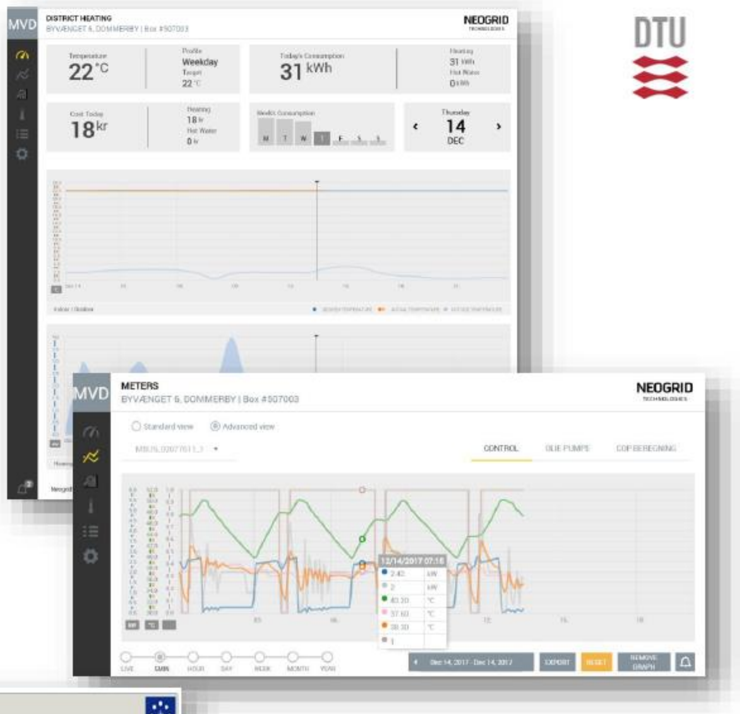


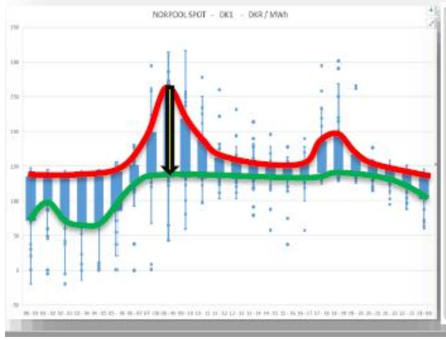
Active system - Heat storage

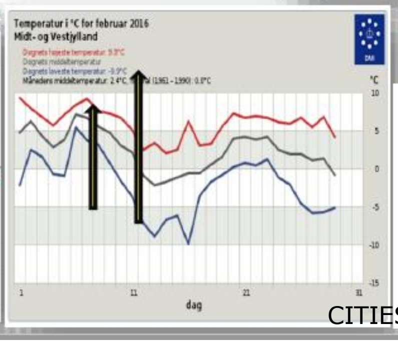
SUNTHERM control

SMART HEAT control:

- Control via internet or app
- Detailed overview
- ✓ Based on prognoses for electricity costs and weather forecasts
- ✓ Solar radiation and wind energy production considered
- ✓ Heat demand for house known 48 hours ahead
- ✓ Heat content of heat storage considered
- ✓ Heat bill as inexpensive as possible







PCM storage:

- Compact thermal battery same size as a fridge.
- 10-25 kWh capacity – temperature 55-66 ^{0}C.
- Low heat loss to surroundings

Intelligent control:

- Controls heat supply based on weather forecast and consumption profile in the house.
- Controls heat production based on energy prices and prognosis.

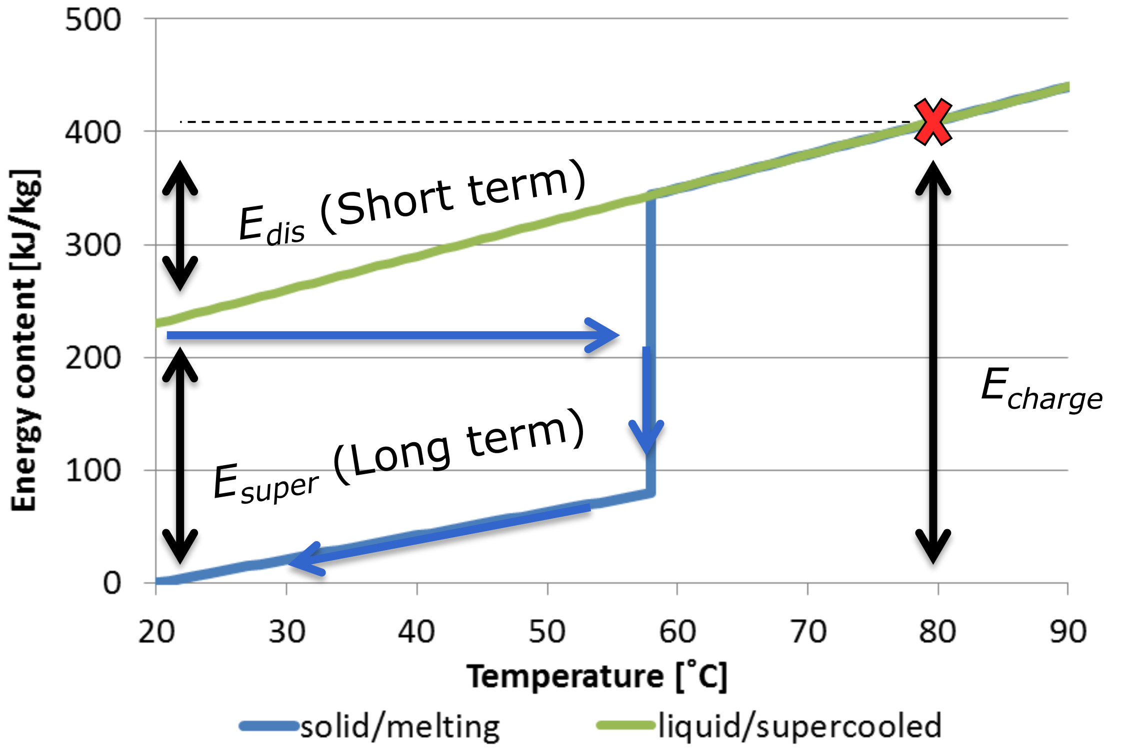
Active system – Long term heat storage

HM
HEIZKÖRPER

https://hm-heizkoerper.de/en/

Principle of long term heat storage: Stable supercooling

- Minimum temperature for stable supercooling ~80°C
  - In all parts of bulk
- Remains in liquid state below melting temperature
- Latent heat of fusion stored
  - Storage period could be months
- Latent heat released
  - When solidification is started



Conclusions

- Phase change materials can be used for passive and active systems
- Match technology and application with demand and supply
- Relatively new technology in the market for the building sector