The transition to decarbonise industry through thermal energy storage

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Energy Efficiency in Industrial Processes

Introduction

Industrial energy consumption within the EU has shown a continuously increasing trend

Shift away from reliance on fossil fuels required to reach Net Zero

Thermal Energy Storage can increase renewable energy supply, facilitate surplus heat recovery and decouple energy supply and demand

DLR Test facility for thermal energy storage in molten salts (TESIS).

Opportunity for Thermal Energy Storage to offset almost 1800 TWh of industrial fossil fuel use and reduce GHG emissions by over 500 Mt CO_2 per year through increased exploitation of renewable energy and greater industrial process efficiency.

Consumption and Sources

Thermal energy demands account for around 80% of the total industrial energy consumption

High temperature processes (greater than 500 °C) consume almost 34% of the energy demand

Industrial heating and cooling is mainly provided by fossil fuel energy sources (90%)

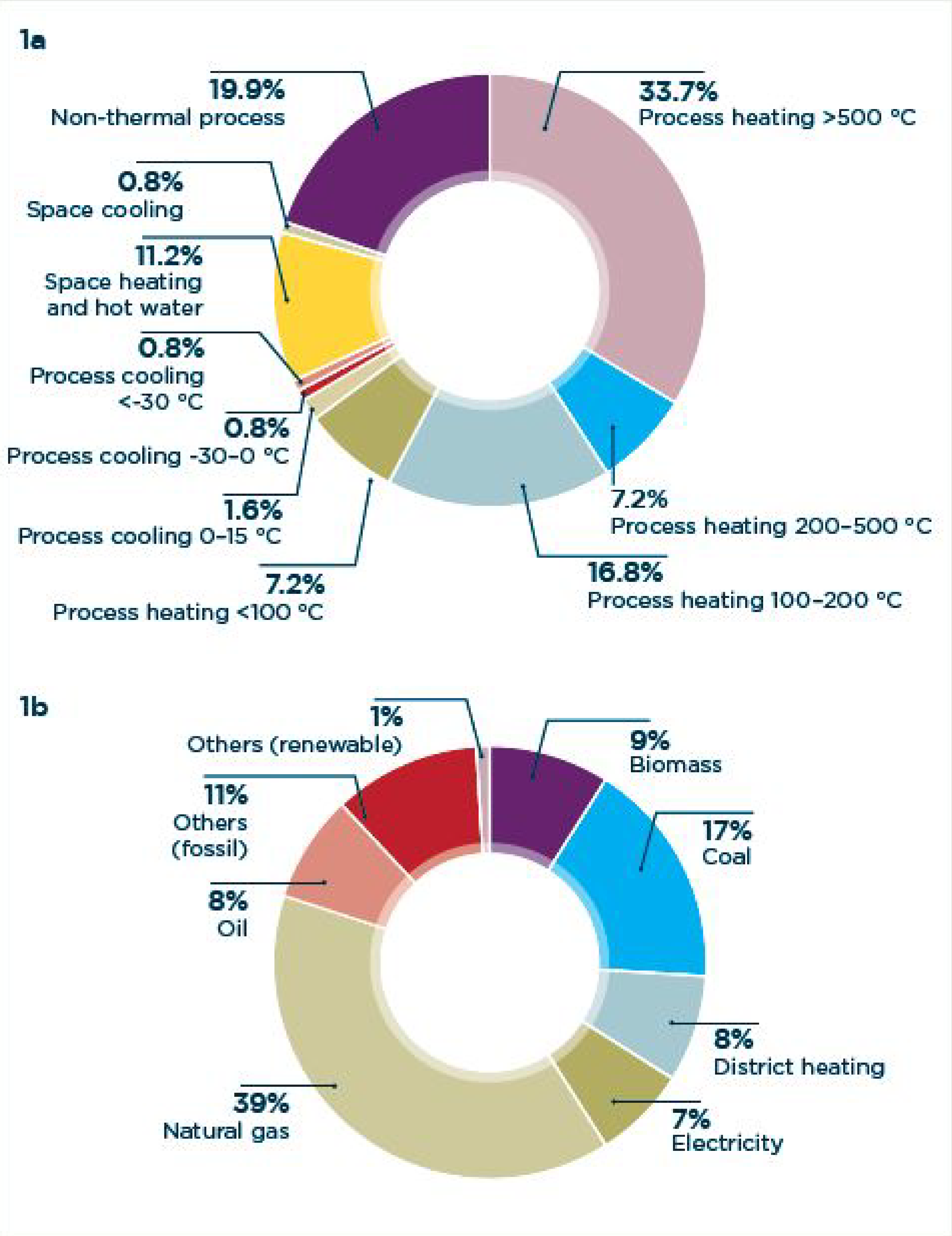


Figure 1 (a) Breakdown of final energy consumption by industries in the EU; (b) Breakdown of energy sources for industrial heating and cooling [1][2].

Applications

Peak shaving

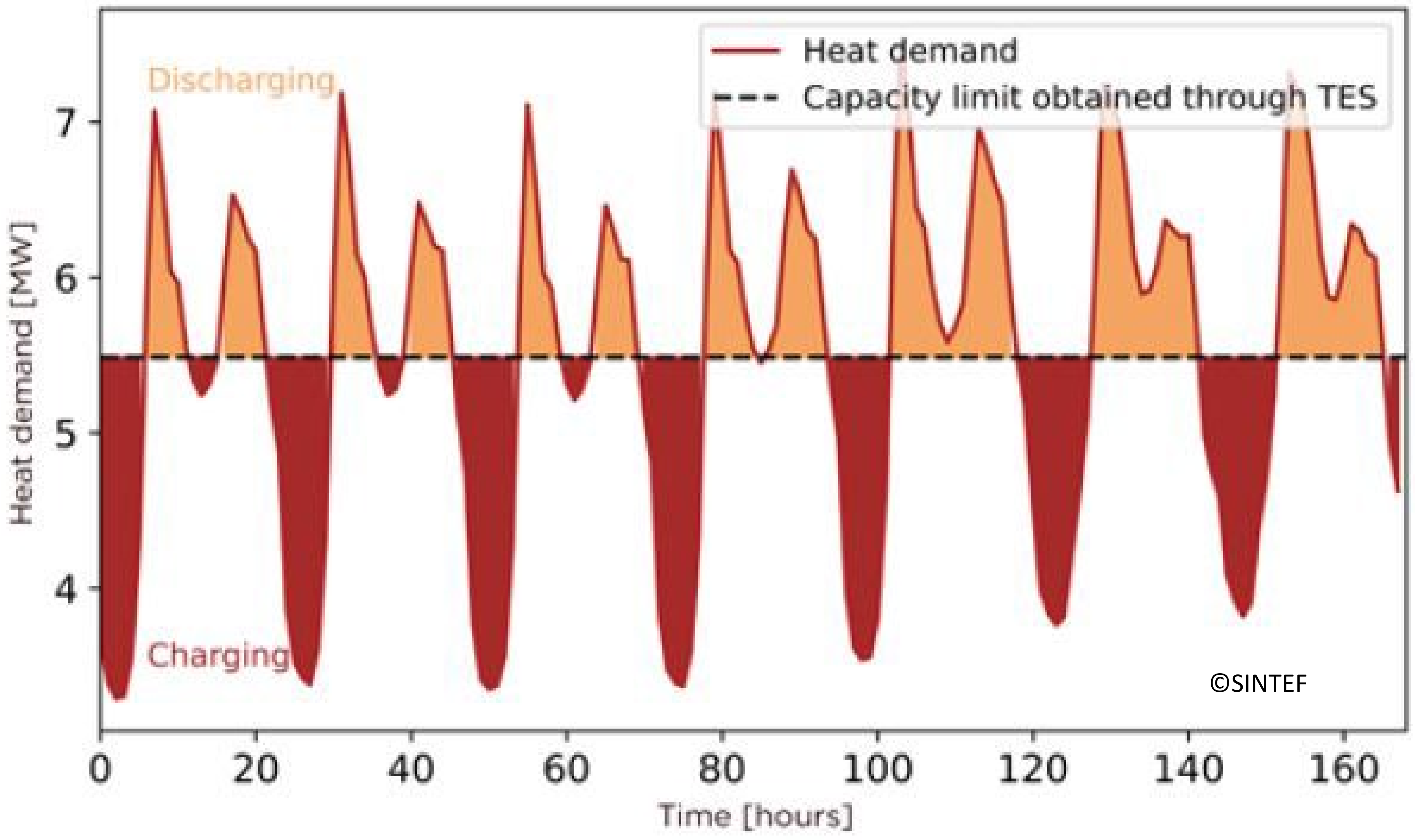
- *store thermal energy when demand low and discharge when demand high.*
- *reduce heating and cooling system capacity and capital cost.*

Thermal buffering

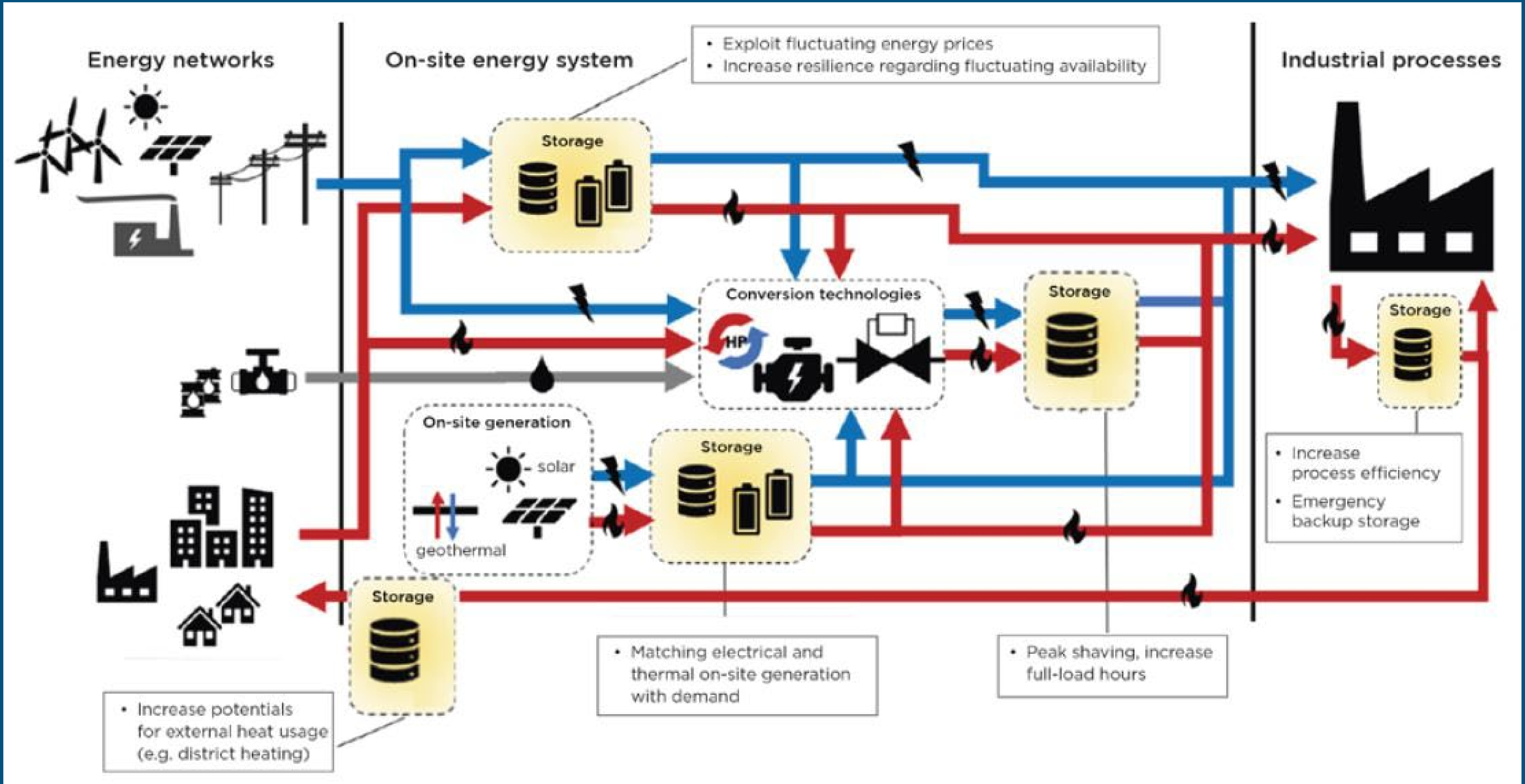
- *fluctuating source e.g. solar and industrial surplus heat.*
- *charge when high availability and discharge when low availability to enable constant or more predictable thermal energy supply.*

Electrification and load shifting

- *electrification of heating and cooling systems will increase.*
- *produce heating or cooling and store when electricity price is low.*
- *reduce operational cost and alleviate pressure on power grid.*
- *increasing grid integration of variable renewable power generation.*



Applications



Technologies

There are four general methods used to store thermal energy:

Sensible thermal storage

- *simple change in temperature of a material.*

Latent thermal storage

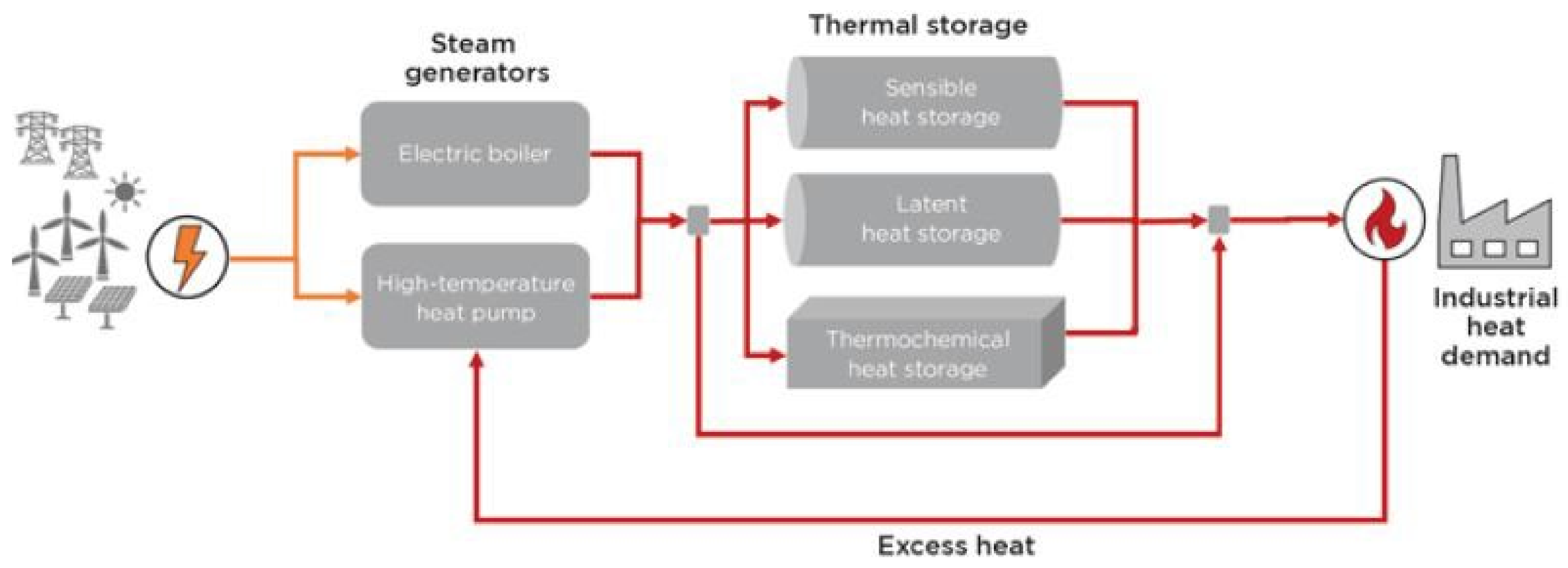
- *phase change of a material.*

Sorption thermal storage

- *reversable reaction between a gas sorbate and a solid or liquid adsorbent.*

Thermo-chemical storage

- *reversable reaction where gas sorbate taken up by a solid altering its crystal structure.*



TES medium		Temperature range, °C	Volumetric energy density, MJ/m^3	TRL
Sensible (ΔT = 50 °C)	Water	0–100	<210	High
	Steam	>100	<125	High
	Stones/ceramic/sand [12]	<1,400	<110	High
	Concrete [12]	<400	<125	High
	Molten salt, e.g. $NaNO_3$-KNO_3 mixtures [13]	150–560	<180	High
Latent (ΔT = 10 °C around melting point)	Aqueous solution, e.g. $CaCl_2$ aqueous solution, ethylene glycol aqueous solution	<0	<150	High
	Ice	0	330	High
	Organic PCMs, e.g. paraffin, fatty acids [14]	0–100	<200	Medium-High
	High temperature organic PCMs, e.g. sugar alcohol, dicarboxylic acids [14]	100–200	<200	Low-Medium
	Salt hydrate [15]	0–100	<350	Medium
	Inorganic salt and metals [16]	<1,000	<430	Medium
Sorption	Absorption, e.g. NaOH solution- water [16]	80–150	900–1,370	Low-Medium
	Adsorption, e.g. Zeolite- water [16]	80–200	170–650	Low-Medium
Chemical reaction (Thermochemical)	Type I, e.g. $CaCl_2$-H_2O, $SrCl_2$-NH_3 [16]	50–200	500–1,500	Low-Medium
	Type II, e.g. $CaO/Ca(OH)_2$ [10]	<1,000	1,000–2,500	Low-Medium
	Type III, e.g. Fe/Fe_3O_4 [11]	<1,800	3,000–26,000	Low-Medium

Technical Challenges

Technology	TES	TRL	Main identified technical challenges	Main applications
Sensible heat storage	Liquid (tank)	9	• Increase volumetric thermal density, therefore reduce space requirements • Reduce high temperatures, pressures, and corrosion for molten salts • Reduce heat losses due to lack of compactness	Hours to days duration of heat or cold storage, where a cheap solution is required, and space-availability is not a challenge
Sensible heat storage	Solid	7	• Increase low gravimetric and volumetric thermal density, therefore reduce space requirements and system weight • Improve heat exchange process	Hours to days duration of heat or cold storage, where a cheap solution is required, and space-availability is not a challenge
Sensible heat storage	Underground (borehole/aquifer)	7	• Reduce very large area requirement • Reduce dependence on specific geological conditions • Reduce high heat losses • Reduce long start-up time • Increase limited temperature range	Large-scale seasonal heat storage under 90 °C where close-to-free heat is available for charging periods
Sensible heat storage	Pit	7	• Reduce space demand at the surface • Improve storage efficiency and impact of temperature levels and the general quality of stratification	Large-scale weeks to months heat storage under 60–80 °C where close-to-free heat is available for charging periods
Latent heat storage	Phase Change Materials (PCM)	4–7	• Increase heat transfer rates, limiting the charge/discharge rates • Improve the process of standardisation and commercialisation of PCMs • Reduce the need for a customised solution for each application • Increase PCM durability (number of cycles) • Improve the purity of thermal storage materials required	Hours to days of heat or cold storage where a compact unit is required
Sorption heat storage	Absorption and adsorption heat storage	6–8	• Increase materials commercially available for applications above 200 °C • Improve efficiency through utilising cold energy produced • Reduce gap between charging and discharging temperatures	Hours to months of heat storage where space availability is a challenge
Thermochemical heat storage	Chemical heat storage (e.g. salt-based reactions)	4–6	• Increase durability and stability of materials • Eliminate agglomeration/lumping issues • Reduce gap between charging and discharging temperatures	Hours to months of heat storage where space availability is a challenge

Non-Technical Challenges

Market

- Lack of awareness on the potential of TES as a source of flexibility and security of supply
- The size of the current market limits the reduction in prices
- Lack of standardised products and integration practices

Operational

- Lack of research and demonstration projects: industry needs to be convinced that technology works
- Lack of sufficiently competent engineers for TES systems
- Lack of TES materials databases with uniform KPI metrics

Financial

- High investment costs
- Lack of incentives specifically directed at TES
- Lack of business models where ownership of the infrastructure is not at the demand side (energy-as-a-service)
- Energy costs mainly dependent on the amount of energy, not peak power
- Lack of energy price structures to support sharing energy resources and increased use of local energy resources

Legislative

- Lack of procedures for certifying the reliability of the technology
- Lack of legislation on the usage of new TES materials and systems in terms of transportation, operation and environment
- Lack of legislation that supports new business models and local sharing of energy resources

Policy Actions

Recognise electrification of industrial processes strongly enhances the need for thermal energy storage

Support demonstration of innovative and commercially technologies and business models

Support targeted R&D programmes to address the technical barriers identified

Take full account of the potential advantages in comparison with other forms of energy storage - available and recyclable materials, lower costs and lower carbon-footprint.

Support dissemination of best practices, knowledge sharing and technology implementation.

Ensure energy efficiency, storage and flexibility are integral part of energy transition plans

Develop clear conditions and long-term perspectives to support longer term investment

Establish independent materials testing institutes to support technical development.

Technical and Business Actions

Conduct R&D projects on TES, focusing on the technical barriers identified

Undertake techno-economic studies of the benefits and its applications

Identify and share applications which have an advantage (economic, environmental, operational) over other forms of energy storage (batteries or hydrogen).

Develop and operate demonstration projects and provide open access results and data.

Share best practices and disseminate knowledge and data

Develop accessible materials databases with uniform KPI metrics.

Work with regulators, professional bodies and industry to develop standardised systems.

Promote and develop new business models

Promote and develop dynamic price structures, adjust the regulatory framework, tariffs, and taxation to accommodate TES and energy flexibility.

White Paper

Industrial Thermal Energy Storage

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