European Association for Storage of Energy

Thermal Storage Position Paper

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Thermal Energy Storage: Key Role in the EU's Energy Transition

Transition in the Heating and Cooling Sector is Vital

The heating and cooling sector is vitally important for the transition to a low-carbon energy system because:

- Heating and cooling is responsible for half of all consumed final energy in Europe. It is the biggest energy sector and is expected to remain so.[1]
- The vast majority – 85% – of the demand is fulfilled by fossil fuels, most notably natural gas.[2] Heating and cooling accounts for 68% of all EU gas imports.[3]
- There are more than 7,000 District Heating Networks (DHN) in Europe, currently supplying more than 10% of total European heat demand.[4]
- 45% of energy for heating and cooling in the EU is used in the residential sector, 37% in industry and 18% in services.[5]
- In terms of energy, heat storage is by far the largest single energy storage application field in Europe.[6]

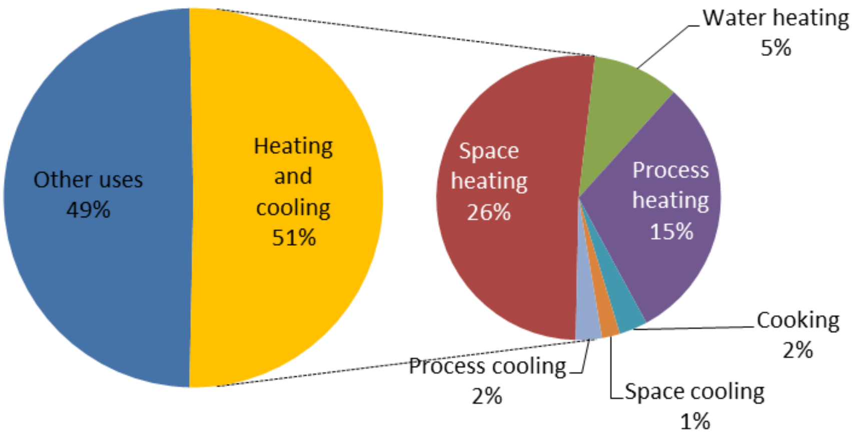

Figure 1: Total heating and cooling demand as share of EU final energy consumption[7]

A significant reduction in the use of fossil fuels to provide heating and cooling services in Europe is the fastest way to reach Europe's sustainability goals. However, the integration of a higher share of renewable energy into the existing power and heating and cooling infrastructure raises challenges in terms of operational variability, grid balancing, and demand

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[1] http://europa.eu/rapid/press-release_MEMO-16-311_en.htm

[2] European Commission (2015). Challenges and Facts. *Heating and Cooling in the European Energy Transition*.

[3] https://ec.europa.eu/energy/en/news/commission-launches-plans-curb-energy-use-heating-and-cooling https://ec.europa.eu/energy/sites/ener/files/documents/1_EN_ACT_part1_v14.pdf

[4] Schmidt, R., Fevrier, N., and Duma, P. (2013). Smart Thermal Grids. *Smart Cities Stakeholder Platform*,

[5] https://ec.europa.eu/transparency/regdoc/rep/1/2016/EN/1-2016-51-EN-F1-1.PDF

[6] EASE/EERA (2013) Joint EASE/EERA recommendations for a European Energy Storage Technology Development Roadmap towards 2030

[7] https://ec.europa.eu/energy/sites/ener/files/documents/Report%20WP1.pdf

response management.[8] Furthermore, putting customers at the centre of the energy market design will also introduce new challenges.[9]

Smart heating and cooling concepts, including thermal storage concepts, have the potential to provide the needed flexibility options – storage, demand response, and smart operation – on the short term and at a relatively low cost.

Smart heating and cooling concepts and infrastructures can therefore play a central role in the transition to a smarter and more sustainable use of heating and cooling, as recognised by the scientific[10] and industry communities[11] and more recently by the policy community[12]. The "Clean Energy for All Europeans" Communication stresses that the proposed package of legislative proposals will *"encourage Member States to increase their share of renewable fuels in heating and cooling, district heating and cooling operators to open up their network to competition and encourage the take-up of for instance heat pumps"*.

[8] Sweco (2015). Study on the effective integration of Distributed Energy Resources for providing flexibility to the electricity system. *Final report to The European Commission*.

[9] http://ec.europa.eu/energy/en/news/vice-president-%C5%A1ef%C4%8Dovi%C4%8D-and-commissioner-arias-ca%C3%B1ete-due-speak-energy-market-design-conference

[10] European Commission (2011). *Energy Roadmap 2050 [COM/2011/885]*.

Heat Roadmap Europe (2016). *Horizon 2020*. Available at: http://www.heatroadmap.eu.

[11] EASE (2016). Position paper on heat and cold storage.

[12] Miguel Arias Cañete (March 2015). Speech: Follow-up to COP21 at the public session of the Environment Council. Commissioner for Climate Action & Energy.

Thermal Energy Storage Accommodates the Implementation of Renewable Energy

A low-carbon energy system requires adaptations to accommodate the changing patterns of energy production and consumption. Energy storage will play a pivotal role in providing the required flexibility and offering balancing options to the integrated energy system. This holds true especially for thermal energy storage concepts, which have unique features and can be used to manage the variations in supply and demand at different scales: large scale district heating and cooling networks[13] and industrial applications, but also at smaller scale for commercial buildings and household dwellings. Even mobile heat storage technology is being studied and tested to offer energy storage and consumption independent from the location of (waste) heat production[14].

Overview of Thermal Energy Storage Options[15,16,17]

Thermal energy storage is a technology that stocks thermal energy by heating or cooling a storage medium so that the stored energy can be used at a later time for heating and cooling applications and power generation. The technology can be grouped into three distinct storage principles:	
Sensible heat storage	Raising and lowering the temperature of a liquid or solid storage medium (e.g. water, air, sand, molten salts, oil or rocks) in order to store and release thermal energy.
Latent heat storage	Taking advantage of the energy absorbed or released at constant temperature during a phase change. In most cases, solid/liquid phase change is utilised, with melting used to store heat and solidification used to release heat.
Thermochemical heat storage	Operating in two ways: chemical reactions and sorption processes. In the former, energy is stored as the heat of reaction of reversible reactions. The latter stores thermal energy either through adsorption (physical bonding) or absorption (uptake/dissolution of a material).

[13] Persson, U., Möller, B., and Werner, S. (2014). Heat Roadmap Europe: Identifying strategic heat synergy regions. *Energy Policy*, vol. 74, pp. 663-681.

[14] http://exhibition.klimaexpo.nrw/projects-pioneers/mobs.html & http://forschung-energiespeicher.info/en/projektschau/gesamtliste/quickinfo-einzelansicht/Latentwaermespeicher-1/kapitel/4/

[15] https://www.irena.org/DocumentDownloads/Publications/IRENA-ETSAP%20Tech%20Brief%20E17%20Thermal%20Energy%20Storage.pdf

[16] http://iea-etsap.org/E-TechDS/PDF/E17IR%20ThEnergy%20Stor_AH_Jan2013_final_GSOK.pdf

[17] http://comtes-storage.eu/home/principal-storage-technologies/

Applications and Key Features

Thermal energy storage systems can roughly be divided into centralised or distributed systems. Centralised applications can typically be applied in district heating and cooling systems, large industrial plants, and combined heat and power plants (renewable or fossil) and/or High Temperature Heat Pumps (HTHP). Distributed storage systems are mostly applied in domestic or commercial buildings for water and space heating or cooling or in combination with heat pumps.[18] Both centralised and distributed thermal energy storage systems empower self-consumption or prosumers across the energy sector, including industrial, residential, community, commercial, and public prosumers. Thermal storage technologies can thus contribute to two core objectives of the "Clean Energy for All Europeans" Package: empowering consumers and putting energy efficiency first.

The most important services delivered by thermal energy storage technologies include:

1. Decoupling generation and demand for heat, power, and cooling.
2. Increasing energy system efficiency, for example by storing industrial waste heat to increase overall system efficiency.
3. Reducing the carbon footprint of the heating and cooling sector using variable, flexible, and base load renewable energy technologies such as wind, solar thermal and PV, biomass, and geothermal technologies.
4. Ensuring security of supply at relatively low cost due to the expansion of the options to supply heat and power in times of high demand.

The choice of services and location specific features of the energy system dictate the technical options and economic value of the implementation of thermal energy storage technology.

Examples of Thermal Energy Storage Applications

1. Increasing system flexibility and empowering consumers through distributed power-to-heat solutions

Heat storage not only increases the flexibility of the heating system, it also provides competitive flexibility to the electricity system in the EU as a whole through system integration options such as power-to-heat solutions.

One such power-to-heat storage technology is **Smart Electric Thermal Storage (SETS)**. SETS are local small-scale storage appliances in which electrical energy is stored within a heavily insulated core as heat, in order to meet householders' domestic space and water heating needs. The latest materials and Information & Communication Technology (ICT) allow this to be achieved in a highly efficient and cost effective manner. The heat storage capabilities of SETS allow the decoupling of the energy supplied to the property for heating, from when the heat energy is required. This intelligent flexibility can facilitate prosumers to reduce the carbon footprint of their space and water heating by maximising the use of locally generated variable solar or wind energy. SETS devices can furthermore be connected to an aggregator service, who manage the devices on behalf of the property owner. This unlocks the potential for the

[18] http://iea-etsap.org/E-TechDS/PDF/E17IR%20ThEnergy%20Stor_AH_Jan2013_final_GSOK.pdf

provision of services that are necessary when increasing the proportion of non-synchronous renewable generation as part of the GHG emission reduction of electricity.

2. Thermal energy storage in district heating and cooling networks

Thermal energy storage can, for example, be implemented in district heating and cooling networks[19] and industry in the form of **Underground Thermal Energy Storage (UTES)** to support the use of waste heat from industry and the implementation of renewable heat sources such as bio-CHP, geothermal, and solar energy. It provides a solution for the 'bathtub challenge' (see figure 2) for regions that have a clear seasonal dip and peak in heating and cooling demand. It allows storage of surplus heat or meeting cooling demand patterns in summer time, enabling overall more efficient use of energy sources. At the dwelling level, heat storage may also provide a sink of heat produced in the summer and production of heat in the winter.

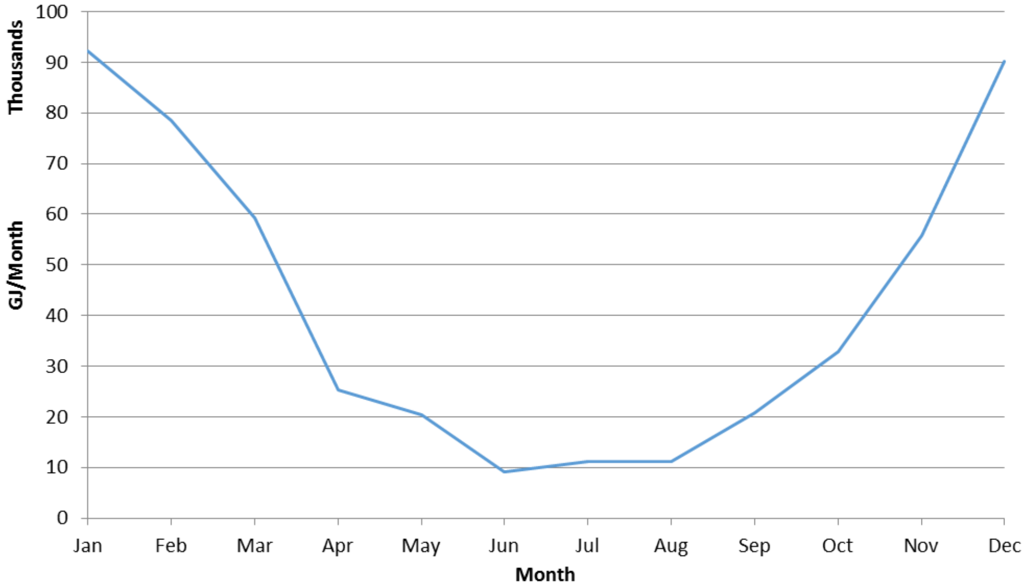

Figure 2: Example of heat consumption profile indicating the summer dip in heat demand and supply. Note that this is a stylised profile for a town in the Netherlands with several thousand dwellings.

[19] A recent study by Artelys, ENEA Consulting and the G2Elab reported that the installation of heat storage on heating networks represents a potential in the order of 5 to 10 GWhth by 2030 in France (Study of energy storage installation potential).
Business case evaluation for thermal energy storage options and power to heat has been performed for case studies and is available at: http://atee.fr/r%C3%A9gion/actualites/rapport-complet-de-letude-de-valorisation-du-stockage-thermique-et-du-power-heat

3. Seasonal buffering of heat through thermal energy storage combined with an existing district heating system

Storage of waste heat from power and industry also provides a means to improve the efficiency of the EU energy system and substantially reduce costs and emissions. Storage of (waste) heat further offers operational flexibility and efficiency gains to power plants and industrial processes.

An example application is a **high temperature Aquifer Thermal Energy Storage (ATES) system** for seasonal buffering of heat with an existing district heating system.[20] The waste (and biomass) to energy facility is the dominant source of heat and currently has a surplus of (renewable) heat in summer and, in time of peak demand, a shortage of supply in winter. Seasonal storage could offer the opportunity to increase the maximum heat supply in winter, thereby reducing the need to deliver heat with (fossil) peak heat installations. The concept has prospective application and replication across the EU.

4. Thermal energy storage combined with a heat pump to integrate waste heat in district heating

Another example is the **combination of a thermal storage technology with a High Temperature Heat Pump (HTHP)**[21]. In industrial processes, waste heat is often generated at completely different locations and temperature levels, which makes this energy difficult to be integrated in the system. In addition, integration of waste heat in district heating grids requires a sufficient temperature level. Low temperature levels and small or intermittent amounts of waste heat are not sufficient to enable the integration of this energy through the use of current waste heat recovery technologies. As a consequence, in most cases, the waste heat dissipates in the environment and primary energy is wasted.

By using the combination of a thermal storage technology with a HTHP, however, the waste heat of a large area such as a chemical park can be merged with an internal district heating system and the temperature can be increased through the use of heat pumps for normal district heating grids or process steam generation. This increases energy efficiency, reduces costs, and improves the environmental footprint. A further advantage of thermal storage is its capacity to integrate very different heat sources, from solar heat to waste heat from clusters of internal combustion engines, required for small but highly flexible and efficient power plants.

The combined application of heat storage and HTHP, possibly coupled with additional electric steam generation, also enables maximum decoupling of heat and power production and avoids additional curtailment of variable renewable producers while increasing the fuel utilisation of existing power infrastructure. As heat pumps in industrial scale can also supply heat and cold at the same time, applications in e.g. food industry would avoid or at least reduce today's parallel production of fossil-based heat or steam and electricity-based cooling.

[20] See for example Denmark, The Netherlands and Germany for underground thermal energy storage applications in operation or under consideration.

[21] "Future Prospects of Industrial Combined Heat & Power in Europe", EuroHeat&Power Magazine, English Edition II/2016.

5. Liquid air energy storage for renewable refrigeration and power supply

Liquid Air Energy Storage (LAES) uses electricity to cool atmospheric air down to -195°C, the point where it liquefies. Liquid air is then stored in an energy dense cold liquid form using low pressure insulated tanks. When electricity is needed, liquid air is pumped, evaporated and expanded through a turbine generating electricity. The evaporation of liquid air releases large amounts of cooling energy. This can be recycled to reduce the amount of electricity needed to produce a kilogram of liquid air and/or integrated into an industrial process. For example, refrigerated food warehouses or food factories. As noted by the Cryo Hub project[22], the integration of LAES into food storage or processing facilities supports the integration of low carbon energy in the power and refrigeration sectors.

[22] CryoHub is a project that has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 691761. More information available on-line at http://www.cryohub.eu/en-gb/

Actions to Reap the Benefits of Thermal Energy Storage in Europe

EASE welcomes the European Commission's commitment to *"look into rules to integrate thermal storage [in buildings and district heating] into flexibility and balancing mechanisms of the grid"*.[23] Given the needed speed and yet high uncertainty regarding the exact roll-out of energy transition across the EU, it is crucial to provide a solid basis for investments in flexibility and balancing technologies. Two messages are important to stress: a level playing field is needed for flexibility and balancing solutions across the energy system and short term actions are needed to reap the benefits of thermal energy storage in EU's energy system.

Level Playing Field for (Thermal) Energy Storage

Without a level playing field for flexibility and balancing solutions, it is highly likely that the energy system will evolve into sub-optimal configurations. This leads to higher overall system costs with lower performance regarding environment and security of supply.

A level playing field is at least required on three levels:

1. **Non-discriminatory economic incentives** for flexibility and balancing solutions. A level playing field could be achieved by equalising market incentives for flexibility solutions, for instance by ensuring that tax incentives (such as accelerated depreciation) also cover (thermal) energy storage technologies.
2. **Non-discriminatory regulatory framework** for flexibility and balancing solutions. I.e. ensuring non-discriminatory access to energy grids; specifically including heating and cooling networks and electricity networks. In particular, EASE encourages facilitating access to district heating or cooling systems for heat or cold.
3. **European Research Development & Innovation** (RD&I) support and efforts should mirror the grand opportunities and challenges ahead for thermal energy storage technologies.

Action is Needed and Timing is of the Essence

Current policy developments indicate a window of opportunity for thermal energy storage. On the one hand, heating strategies on national and local levels are being revised. On the other hand, energy independence and security of supply issues are increasingly prioritised in the policy agenda. Policy makers are pursuing a path of moving away from fossil fuels while still meeting heat and cold demand across the EU.

Short term actions can further leverage the proposed actions in the "Clean Energy for All Europeans" Package. Three concrete actions are therefore proposed:

- Initiate potential assessments and communication of the benefits of thermal energy storage options for prosumers, industry, and communities; among other flexibility solutions. The focus here should be on two underexposed applications: the way consumers could benefit from the use of thermal energy storage as well as the potential of thermal storage at the industrial and commercial level. This includes finding

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[23] Communication 2016/51 from the Commission on "An EU Strategy on Heating and Cooling" https://ec.europa.eu/energy/sites/ener/files/documents/1_EN_ACT_part1_v14.pdf

solutions to barriers to self-consumption and the active participation of prosumers in markets.

- Steer towards achieving non-discriminatory market incentives and regulatory frameworks across the EU for flexibility solutions. The focus here should be on removing infrastructure access barriers for flexibility technologies and services, including energy storage technologies. One discriminatory market incentive is the setting of the Primary Energy Factor (PEF) at a default of 2.5 in the EU, which makes electric heating and cooling appear inefficient compared to other technologies. This could disadvantage thermal storage technologies in the market, even if they support the decarbonisation of the heating and cooling sector. Other technology-specific barriers can be found in the annex of this paper.
- Demonstrate and deploy support of (new) integrated solutions where pre-commercial thermal energy storage options are implemented in smart energy systems[24] to reach the required flexibility at lowest system costs. The key is to reap the benefits of the portfolio strength of thermal energy storage technologies: from small to large scale and from short term to seasonal storage solutions.

The timing should be well before shares of RES have grown towards targeted levels and supply from fossil resources has phased out. EASE believes that these proposals would support the EU's goals to empower consumers, improve energy efficiency, and reduce GHG emissions in the energy sector, including the often underexposed heating and cooling sector, in a cost-effective way.

[24] *"Smart electricity, thermal and gas grids are combined and coordinated to identify synergies between them in order to achieve an optimal solution for each individual sector as well as for the overall energy system."* Lund H. Renewable Energy Systems – A Smart Energy Systems Approach to the Choice and Modelling of 100% Renewable Solutions. 2014.

Annex: Technology-Specific Barriers

Category	Type of Thermal Energy Storage (TES)	Barriers
All TES technologies		• Upfront cost of TES • Lack of energy (electricity, heat) balancing markets and price signals: for an improved value proposition for different TES technologies, time-of-use tariffs and price signals for time shifting would likely be a driver for the uptake of TES • Slow uptake of renewable heating technologies • Large scale seasonal TES: low penetration of district heating and slow uptake of renewable thermal sources • Knowledge and awareness in society, public sector and industry • Research gaps and project demonstration
Sensible heat storage	Tank TES (TTES)	• Cost, length, complexity and heterogeneity of procedures • Space constraints, limiting clauses (e.g. permissible temperature, maximum drilling depth) and requirements for site investigations or monitoring are adding to the cost of the final system
	Pit TES (PTES)	• Underground space constraints and lack of subsurface spatial planning
	Borehole TES (BTES)	• Land costs and space constraints
	Aquifer TES (ATES)	• Excessive costs, length and complexity for the issuance of ATES systems permits • Stringent planning and monitoring requirements
	Smart Electric Thermal Storage heaters (SETS)	• Regulatory framework: the primary energy factor of 2.5 for electricity makes electric heating and cooling appear inefficient in comparison to other technologies • Electric heating is counteracting with energy efficiency policies • Balancing markets which accept no or only high minimum load • Absence or delay in roll-out of smart meters across EU countries
Latent heat storage	Phase change material (PCM)	• Low renewable heat penetration • The use of combi boilers and hot tanks are considered as a proven barrier to PCM deployment
Thermochemical heat storage (THS)		• Pre-commercial technology requires demonstration. • Size reduction and improved materials needed • Household to housing block sized heat batteries: barriers to prosumerism, reaching autarchy and decentralised solutions

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The European Association for Storage of Energy (EASE) is the voice of the energy storage community, actively promoting the use of energy storage in Europe and worldwide.

EASE supports the deployment of energy storage as an indispensable instrument to improve the flexibility of and deliver services to the energy system with respect to European energy and climate policy. EASE seeks to build a European platform for sharing and disseminating energy storage-related information. EASE ultimately aims to support the transition towards a sustainable, flexible and stable energy system in Europe.

For further information, please visit www.ease-storage.eu

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Disclaimer:

This response was elaborated by EASE and reflects a consolidated view of its members from an energy storage point of view. Individual EASE members may adopt different positions on certain topics from their corporate standpoint.

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