SYSTEMIQ

CATALYSING THE GLOBAL OPPORTUNITY FOR ELECTROTHERMAL ENERGY STORAGE

PROMISING NEW TECHNOLOGIES FOR BUILDING LOW-CARBON, COMPETITIVE AND RESILIENT ENERGY SYSTEMS

EXECUTIVE SUMMARY

FEBRUARY 2024

With the support of Breakthrough Energy

1 Decarbonisation of industrial heat is necessary to avoid the worst impacts of climate change and solutions are available today.

To ensure that global temperature rise stays well below 2°C, as countries pledged to in the Paris Agreement, reaching net-zero greenhouse gas (GHG) emissions by mid-century is critical. Industrial heat generation is a large contributor to the total GHG emissions today. Heat is a very important contributor. In 2019, heat accounted for 50% of energy end use and 40% of global carbon dioxide (CO_2) emissions.[1] About 50% of all heat produced is used for industrial processes, which leads to almost 20% (6 gigatonnes) of global CO_2 emissions.[2] These are emissions from boilers or furnaces in which fossil fuels, such as gas, oil or coal are combusted to create heat.

Decarbonisation of industrial heat is critical to reach net zero and it is technologically possible, even though there are still barriers to overcome in economic competitiveness and technology readiness, particularly for high-temperature processes (above 400°C).

Commercially available technologies to electrify industrial heat today are heat pumps, electric boilers and, for some applications, electric furnaces. This report focusses on electrothermal energy storage (ETES), emerging commercial technologies, which are promising systems to contribute to decarbonising industrial heat.

2 ETES technologies are commercially available and electrify industrial heat processes with the additional ability to store energy in the form of heat.

ETES technologies use electricity to produce heat and then store it in a heat storage medium such as bricks. Systems can charge when electricity is cheapest, which is typically when there is excess renewable electricity production. The stored heat can then be used to generate a continuous flow of heat on demand. Models commercially available today can deliver heat up to 400°C, typically as hot water or steam. As such, ETES can replace fossil fuel–based industrial boilers. Figure ES1 demonstrates how different types of ETES technologies work.

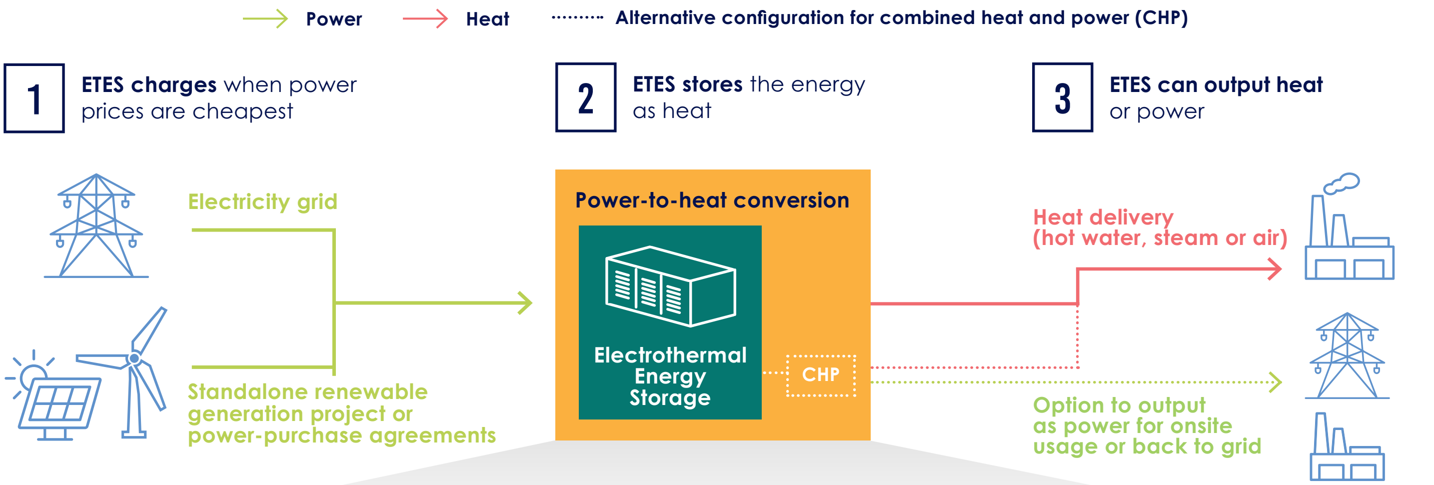
ETES technologies are widely applicable as virtually all industrial sectors have at least some processes requiring heat in these temperature ranges. In some sectors ETES could cover all heat demand, such as in the food and beverage manufacturing and paper and pulp sectors. These sectors typically require temperatures up to 400°C. ETES systems that provide higher-temperature heat up to 1,500°C are under development and are targeting rollout by 2030. Heat for processes such as biorefining (up to 600°C), steel preheating (up to 700°C) and clinker preheating (up to 900°C) could then be addressed by an ETES system.

ETES is especially relevant for industrial sites and other processes that require heat continuously and want to use energy from wind or solar instead of from fossil fuels to fulfil their energy needs. ETES can also be configured to generate power from the stored heat, alongside steam.

1 "Renewables 2019, Heat," IEA, 2019.

2 "Energy System Overview, Industry," IEA, 2023; and "Decarbonization of Industrial Sectors: The Next Frontier", McKinsey 2018.

Figure ES1 How different types of ETES technologies work



Landscape of ETES technology types and providers

	SENSIBLE HEAT	LATENT HEAT	THERMOCHEMICAL HEAT
How it works	Increases temperature of a solid or liquid medium	Changing material phase	Endothermic and exothermic chemical reactions
Temperature range	<0 to 700°C *In progress to reach more than 1,500°C*	*In progress to reach 1,600°C*	*In progress to reach 900°C*
Storage duration	Intra day to days (or months at lower temperatures)	Intra day to days	Intra day to months
TRL	Commercially available	R&D to commercial available	Nascent
Providers (non exhaustive)	Antora, Brenmiller, Echogen, Electrified Thermal Solutions, EnergyNest, Kraft Block, Kyoto, Magaldi, Malta, Rondo, Storworks, 1414°	Azelio, MGA Thermal, TORC, Thermophoton, 1414°	redoxblox, SaltX

Source: Company websites; *Net-zero heat: Long Duration Energy Storage to accelerate energy system decarbonization*, LDES Council, 2023.

3 ETES could reduce the equivalent of up to ~40% of 2022 global gas use and the equivalent of up to 14% of global energy-related greenhouse gas (GHG) emissions by mid-century.

The electrification of industrial heat reduces a country's dependence on fossil fuels and enables decarbonisation. In regions that rely on the import of fossil fuels, energy independence and resilience will also improve.

Commercially available ETES systems today are mostly applicable to industrial processes that use hot water or steam for heating. These are most common in the food and beverage, chemicals, textiles and paper and pulp sectors. With these applications, it is estimated that by 2030 ETES has the potential to electrify the equivalent of ~8% of current global gas use. This translates into abating the equivalent of up to ~2% of global energy-related GHG emissions.

Besides these applications, ETES technology development is anticipated to unlock higher-temperature industrial applications such as clinker preheating and steel direct reduced iron (DRI) preheating. On top of that, ETES applications will expand to cover emerging demand for new energy-related processes, such as green chemicals and sustainable aviation fuel, that will grow with advancement of the energy transition.

Finally, nonindustrial markets such as district heating (that can already be addressed today, as is currently trialled in Denmark) and direct air carbon capture (a market that could develop after 2030) could be an additional opportunity for ETES. These additional applications could grow the addressable market by almost 2.5 times. By mid-century, ETES could displace the equivalent of ~30%–40% of current global gas use and abate up to 14% of today's energy-related GHG emissions.

4 ETES can help balance electricity demand and supply, reducing the need for grid expansion and supporting the expansion of renewable electricity generation.

As electricity systems rely more and more on variable sources of wind and solar power, matching this variable supply with flexible demand and/or storage increasingly becomes a prerequisite. ETES can help reduce electricity demand peaks (by up to 6%–30%) compared with other industrial electrification technologies in the countries analysed. This reduces the costs of grid expansion because electricity grids are typically sized to accommodate peak demand.

ETES can also help the power system by using (excess) renewable electricity at times of high solar and wind generation, therefore reducing curtailment levels in the power system. This way, ETES is estimated to enable an average of ~2.6× its own capacity in renewable generation capacity to come online. This means, in addition to its own electricity use (many ETES technologies can generate electricity in addition to heat), ETES is estimated to enable an average extra 1.6 megawatts (MW) of variable renewable power generation to come online.

5 ETES can provide flexible electricity demand for industrial heat that is relatively energy efficient and requires lower investment while using widely available materials.

Allowing for flexible electricity demand will be a crucial feature of industrial electrification. The high efficiency of ETES (90%–95% from grid electricity to heat) and comparatively lower investment costs (the capital expenditure per kilowatt of grid-scale battery systems can be more than double the capital expenditure required for ETES) make them more cost effective than adding battery storage to electric boilers and in some cases even to heat pumps. ETES value chains can be local. ETES technologies rely on widely available materials, such as bricks, and do not require the scarce minerals that batteries need. These benefits can be unlocked today with actions from market players, technology providers, industrial users, regulators and grid operators.

6 ETES has benefits over other electrification of heat technologies in temperature reach, ease of installation and storage capability.

ETES is expected to be part of the technology mix used to generate low-carbon industrial heat. Heat from hydrogen is not yet commercially available and is expected to be considerably more expensive than ETES due to the energy losses in the hydrogen production process. Heat pumps are more energy efficient converting electricity to heat than ETES (200%–300% efficiency for a heat pump versus 90%–95% for ETES) and thereby typically more cost-competitive than ETES. However, heat pumps can require extensive on-site changes, and heat pumps cannot reach temperatures above 200°C yet — while more than half of industrial heat demand is for temperatures above 200°C.[3] Electric boilers can provide the same temperatures as ETES-based boilers can reach today. Future electric furnaces are expected to be able to reach similar temperature levels (above 1,000°C) as future ETES systems as both technologies develop further. However, the inflexible baseload demand of heat pumps, e-boilers and e-furnaces requires additional investment — either in the electricity network or in on-site storage — to translate intermittent electricity from renewables into continuous electricity.

3 "Industrial Heat Demand by Temperature Range," IEA, 2018.

Financial support to close a cost gap with fossil fuel–based heating is better spent on ETES than on hydrogen-based technologies. ETES technologies are more cost-competitive per tonne of carbon abated than green hydrogen–based technologies for applicable industrial processes. ETES can be (close to) cost-competitive with gas boilers today, whereas heat from hydrogen boilers can be three to five times more expensive than gas boilers.

7 In most regions, ETES faces barriers in affordability and accessibility compared with gas boilers.

Natural gas boilers are the incumbent industrial heating technology in Europe and the United States. While some hurdles remain, ETES is projected to be generally competitive with natural gas boilers by 2030 in Spain. In all regions that were analysed, ETES may be competitive when optimised for a specific site (e.g., bespoke grid fee agreement and power purchase agreement or on-site generation). However, in Denmark, France, Germany, the Netherlands, the United Kingdom and the Texas ERCOT region in the United States, the levelised cost of heat (LCOH) of ETES is higher than that of natural gas boilers. This is because in these regions electricity grid fees and taxes are higher than grid fees for natural gas, and wholesale electricity is more expensive than natural gas per unit of energy.

ETES is also less accessible compared with natural gas boilers due to electricity grid congestion, which can lead to waiting times of up to 10 years in some regions. Without any changes to regulations, the benefits of ETES are unlikely to be unlocked due to the barriers above. However, with realistic, targeted actions, regions can remove the barriers to at scale deployment.

8 Policymakers and grid operators can act now by removing barriers and accelerate a tipping point in the uptake of ETES.

Policymakers and grid operators are crucial stakeholders in shaping the market conditions for ETES. The regulation of electricity markets and industry decarbonisation has a significant impact on the affordability and accessibility of ETES. Based on the regions studied for this report (Denmark, France, Germany, the Netherlands, the United Kingdom, Spain and the Texas ERCOT region in the United States), the most important actions are:

- **Reform grid fees, taxes and discounts to incentivise grid power usage during least-used periods.** The cheapest grid costs should be for usage that is least cost to the grid (i.e., flexible or off-peak usage), but this often not the case today. Grids are planned to serve peak load. Therefore, grid costs (fees, taxes and levies) and associated discounts could be aligned with how much usage profiles add to the peak load.
- **Introduce criteria to fast-track grid connection for flexible demand technologies.** Flexible demand could reduce grid congestion issues and avoid grid expansion costs. However, there is currently a long wait time (of up to 10 years in some regions) to be connected to the grid. Some regions are proposing prioritising renewables and electricity storage connections. Even though ETES may even reduce grid congestion (depending on charging schedule), it has not yet been considered for prioritisation.
- **Ensure that ETES is eligible for industrial decarbonisation, energy storage and flexible demand support schemes.** ETES being a relatively new technology means it is often not included in support schemes. Doing so would not only enhance energy security and reduce industrial emissions, but also benefit the decarbonisation of the wider electricity and energy systems. Even today the affordability gap can be closed without subsidies in certain countries and setups. Subsidies put in place today will provide business case certainty for cost effective decarbonisation of heat to be implemented by 2030. Most business cases made today will include the LCOH around 2030 and beyond. Analysis shows that dedicated subsidies are not required in 2030 in the countries analysed if other levers are actioned.

9 Technology providers can act now by increasing awareness of ETES, and by working with industry users to ensure the optimal configuration of the ETES asset for the specifics of the site.

Technology companies and industrial users also play a critical role in raising the awareness of ETES and ensuring that ETES is factored into future site plans. Key actions are:

- **Technology companies can continue to raise awareness of ETES benefits** through continued stakeholder engagement.
- **Technology companies can tailor their product offering** to promising market segments, which can include combined product offerings with utilities and grid operators to provide charging optimisation and grid connection.
- **Industrial users can evaluate ETES technologies for heat provision on their sites** and put in place an action plan for sites where it makes economic sense. Larger industrial hubs can explore the possibility of combined heat provision for the entire hub. As part of this they can work with technology providers to ensure their ETES setup is optimised for the specific site characteristics, such as local grid congestion charges, governmental support schemes, operating hours and grid fee structure.
- **Industrial manufacturers can explore whether there is an appetite for a green premium for their products to cover any cost increase from using ETES,** which could be incentivised by regulations or corporate commitments to a lower product carbon footprint.

This executive summary is an extract from the report *Catalysing the Global Opportunity for Electrothermal Energy Storage: Promising New Technologies for Building Low-Carbon, Competitive and Resilient Energy Systems.* The full report can be found at **https://systemiq.info/etes**.

This report was developed by Systemiq with the support of Breakthrough Energy.