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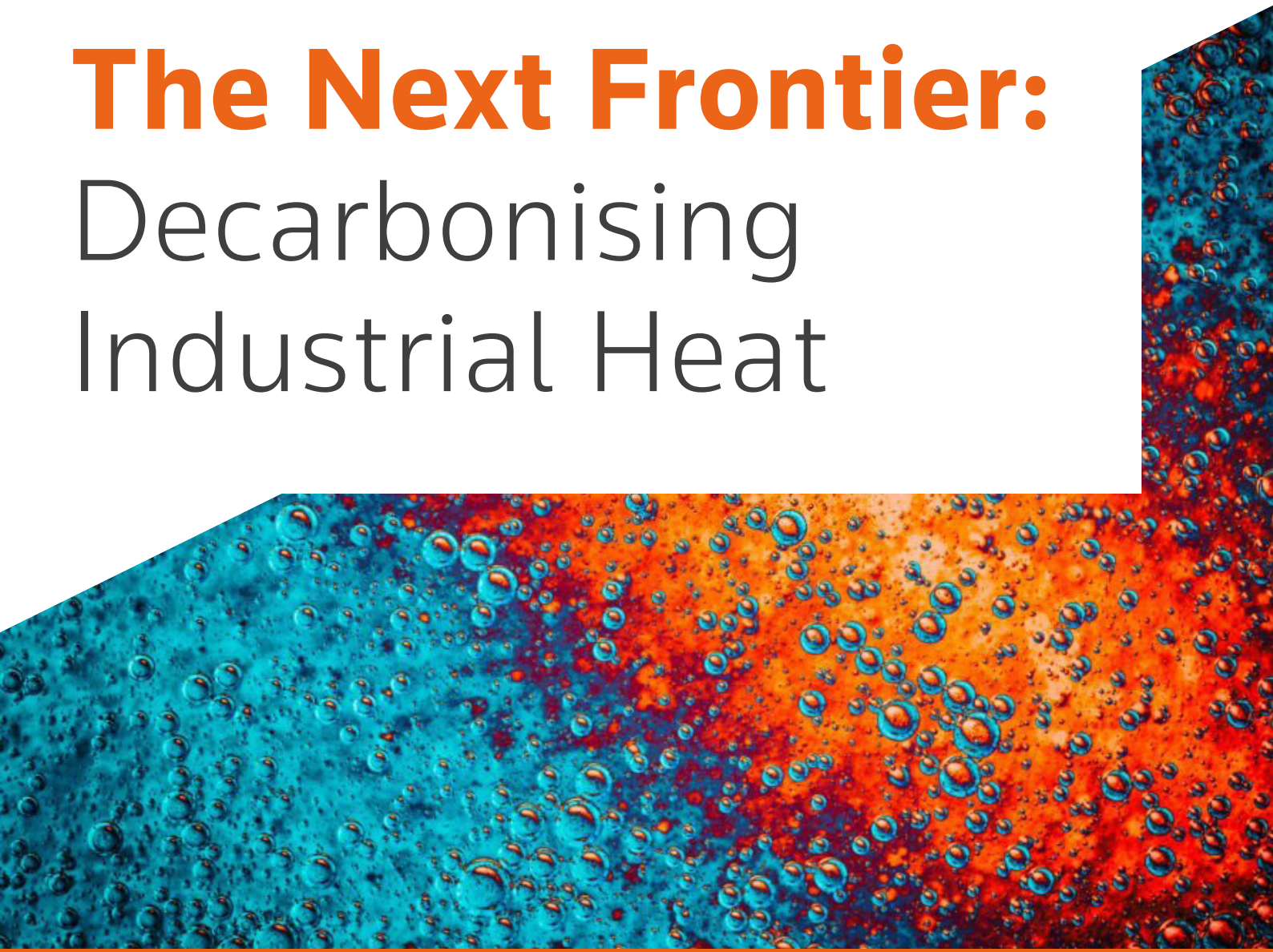
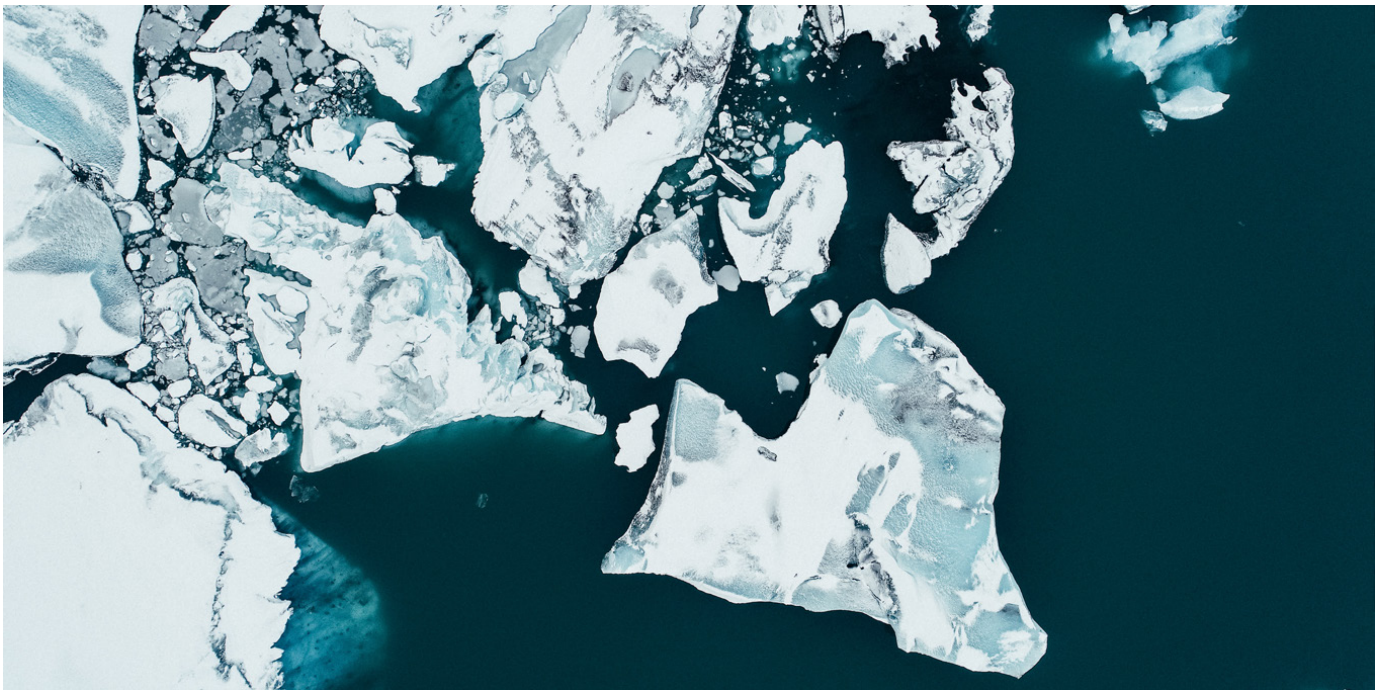
EnergyNest | The thermal battery company

The Next Frontier:
Decarbonising Industrial Heat





Introduction

April 2022 saw the Intergovernmental Panel on Climate Change issuing its starkest-ever warning on carbon emissions, which indicated that time has run out for delay. From now on, "every fraction of a degree of extra warming increases the risk of devastating climate change and severe weather events," said Professor Corinne Le Quéré FRS, Royal Society research professor of climate change science at the University of East Anglia.[i]

Yet some sectors still have a long way to go on emissions reductions. The industrial sector, for example, largely depends on fossil fuels to meet its vast energy demand. Heat, almost entirely generated by fossil fuels, makes up two-thirds of industrial energy demand across all industrial processes and almost one-fifth of global energy consumption.[ii] Industrial carbon emissions represent 29 percent of global greenhouse gas output in an average year.

Decarbonising this source of emissions is critical as the global economy charts a course to a more sustainable future. It also represents a significant low-carbon market opportunity, since the volume of emissions to be abated is so large. But today industrial heat decarbonisation is a Cinderella challenge: it has been severely neglected so far and desperately needs addressing. Fortunately, there is a growing array of options to solve the problem.

This paper, produced in partnership with EnergyNest, a thermal energy storage technology developer and green heat provider, looks at the options for industrial heat decarbonisation. It introduces a cost-effective, sustainable and reliable route to carbon reduction for a wide range of industrial applications.

Fossil fuels in industrial heat

Almost all industrial processes, ranging from mining, steel production, food & beverage, manufacturing, chemical synthesis, dairy production, cement making and many more, cannot take place without the production of heat. And since the industrial revolution, that heat has been created almost exclusively using fossil fuels, which have embedded storage. Fossil fuels have historically been used because they have been readily available at relatively low cost, says Bryan Fisher, managing director of the climate-aligned industries programme at RMI, a non-profit energy conservation organisation in the United States.

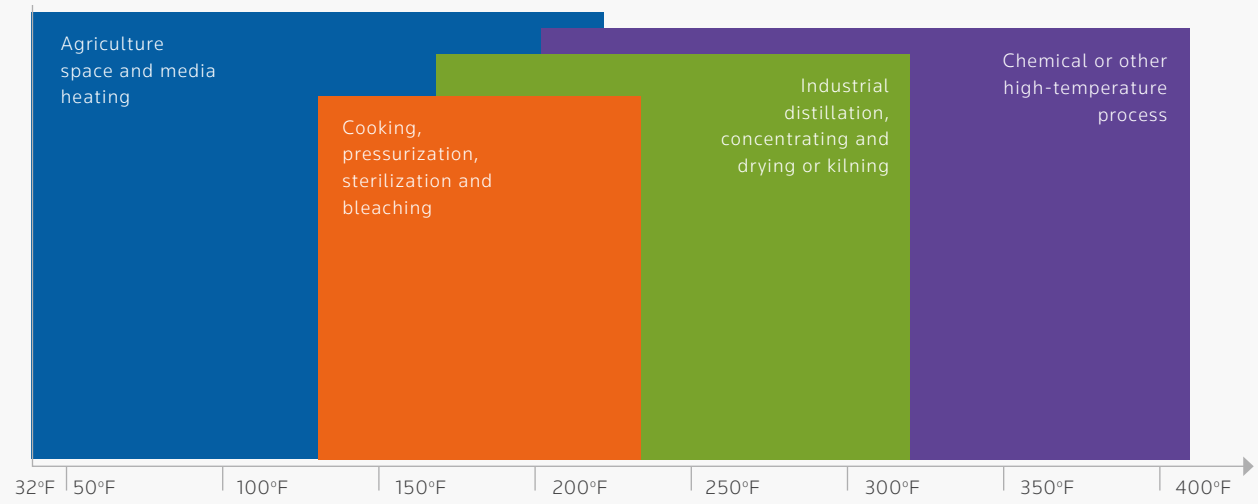
In many cases, there are low-carbon alternatives to fossil fuels that can be utilized to deliver heat. "The hard part of decarbonising heat production for industry has been getting low-carbon fuels to cost parity, but this is changing, and permanently," Fisher comments. "The specific challenge changes depending on what kind of industrial heat process you are talking about."

While industries such as cement or steel production require very high temperatures, half of the heat used by industry around the world is for processes such as paper or plastics manufacturing that require less than 1,000 Celsius (1,832 Fahrenheit). Although it is possible to electrify such low-heat processes, it has historically been expensive to do so, and the technology was not there to match cheap, green yet volatile renewable supplies with constant industrial demand.

"The good news is that it is now increasingly economically attractive for producers to electrify

Heat applications in industry

(32 F = 0 C; 400 F = 204 C)



Source: United States Environmental Protection Agency.[iii]

low-heat processes, as the cost of renewable energy is at or below grid parity," Fisher says. "As prices drop, electrification will save producers money today and in the long term."

The move away from fossil fuels is being hastened, particularly in Europe, by concerns over Russian oil and gas dependency in the wake of Russia's invasion of Ukraine. Europe's REPowerEU plan, for example, says: "Replacing coal, oil and natural gas in industrial processes will reduce greenhouse gas emissions and strengthen security and competitiveness."[iv]

However, relying on renewable energy directly for green heat generation across the industry leads to other challenges. Electricity from wind and solar is intermittent in nature, meaning that at some times it may be expensive or even unavailable. This makes it a poor match for the round-the-clock heating requirements of many modern industrial processes. Adding to this mismatch, the heat and steam needs of industry may indeed not be constant, but batch process driven, so matching them to intermittent energy supplies requires a new approach.

The problem is likely to become more complex as the energy transition proceeds and industry increasingly competes with other sectors, such as transportation, for electricity. Reliability of energy supplies could become a bigger concern for the industry in future, requiring solutions that can provide green heat capacity on tap.

"The diverse nature of industry presents a challenge for decarbonisation of heat," says Emma Ashcroft, associate director of the Carbon Trust, a British carbon management and reduction body. "There is no silver bullet technology applicable for all sectors and, in fact, a wide range of technologies is likely to play a role."

The options for industrial heat decarbonisation

The decarbonisation options for industrial heat essentially fall into five categories, as follows.

Biomass
Provided it is produced sustainably, biomass can be used as a substitute for fossil fuels in some industrial settings. The Danish energy company Ørsted, for example, has fully decarbonised its heat production, including steam deliveries to industries in Kalundborg, by using sustainable biomass instead of coal as fuel for combined heat and power units (CHPs).

Using this route, "Today Ørsted delivers CO2-neutral heat and steam to its customers," says Jens Andersen Grymer, Ørsted's senior director of bioenergy customers and asset portfolio.

The issue for this decarbonisation category is whether supplies of sustainable biomass can be scaled up without affecting food production or habitat preservation.

Electrification
Electricity can and will be used to provide heat for many industrial processes. In steelmaking, for example, electric arc furnaces can heat foundries to up to 1,800 C (3,300 F). However, most industrial heat applications are between 150 C and 440 C and need some form of thermal storage to deliver energy reliably and overcome intermittency.

Meanwhile, "as electricity production is increasingly decarbonised, and the price of renewable production is falling, an option is to electrify heat production in industry using industrial heat pumps, particularly for low-temperature applications," says Ashcroft.

The use of heat pumps in many industrial settings is debated, however. "The industrial heat pumps currently available in the market can only supply heat up to 180 C [356 F], which isn't sufficient for more than 50 percent of industrial applications," Ashcroft notes.

Fossil fuels with carbon capture

Another option is to carry on using fossil fuels but to reduce their emissions using carbon capture and storage (CCS) technology. This strategy is already being used by some industrial players and is particularly important for processes such as steel production where hydrocarbons serve as a chemical reactant as well as providing heat.

However, new CCS projects have long lead times and could add significantly to the cost of industrial processes, as well as potentially extending a dependence on oil and gas-producing nations that has been called into question following Russia's invasion of Ukraine. Plus, there are questions over the efficacy of the technology,[v] versus renewable energy, which is already proven at scale.

In the long run, it is likely that the use of fossil fuels in industry will be superseded by alternative approaches like electrification of industry, or low-carbon substitutes such as biofuels.

Low-carbon hydrogen

For high-temperature processes especially, there is growing interest in replacing fossil fuels with alternative energy carriers that do not release carbon on combustion. Foremost among these is hydrogen, which can be produced with low emissions either by adding CCS to traditional steam methane reforming synthesis or by using renewable energy for the electrolysis of water.

"Electrolyzer technology has been around for a hundred years," remarks Fisher. "It is proven and scalable. But investment is needed to develop the supply chain."

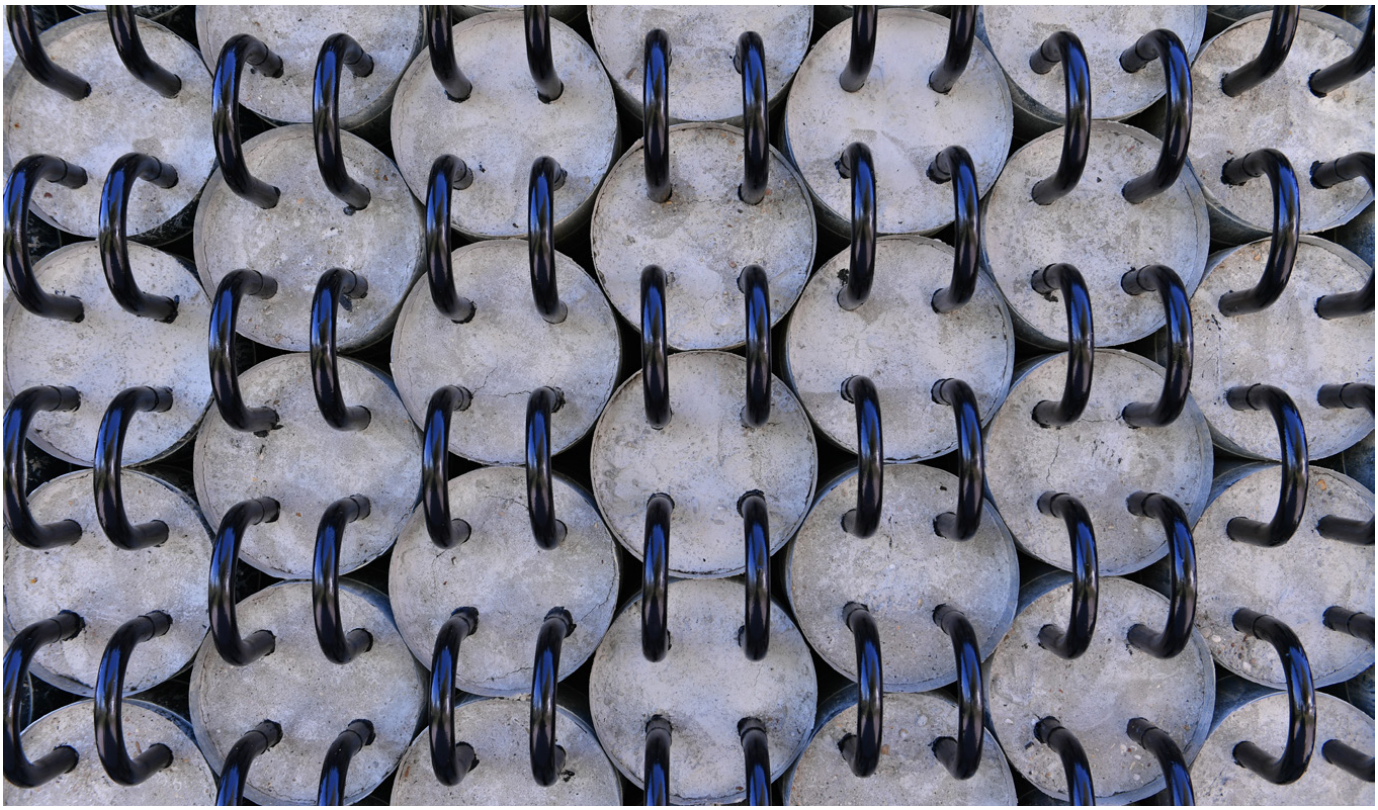
Industrial applications are seen as a key market for low-carbon hydrogen. However, a potential drawback for hydrogen made from electrolysis is that projects have long lead times, and the production process is inefficient, which can lead to high costs relative to alternatives.

Thermal storage

One emerging cleantech field that could have significant impact on the industrial sector is thermal energy storage. Thermal energy storage enables industry to capture excess or low-cost renewable electricity by warming up a storage medium to temperatures of up to around 400 C (752 F), so far higher than what can be achieved with heat pumps.

Thermal energy storage provides low-carbon heat and steam delivery on demand and is cost-competitive, flexible, reliable, scalable for industrial applications up to gigawatt-hour requirements. "We need to make sure that thermal storage is part of the mix and is an option for industrial customers," says Ben Francis, director at Infracapital, a leading European infrastructure investor that has invested 110 million euros ($118 million) in EnergyNest.

"There are benefits to thermal storage over hydrogen and CCS. It's more cost effective. It's available now and it's not dependent on a change in gas to hydrogen or some form of technology, which still isn't readily available and cost effective."



Thermal storage in action

A 2020 study by Aurora Energy Research on behalf of EnergyNest estimated the global market for industrial heat could be worth more than 300 billion euros ($313 billion) by 2030. That was said to be more than three times the total market for utility-scale electrical batteries.[vi] EnergyNest's ThermalBattery™ technology is already making inroads in the market, with operational projects including the following.

Yara fertiliser plant
The fertiliser industry holds a huge potential for decarbonisation using thermal storage because of the range of temperatures required for fertilizer production. Fertiliser maker Yara International integrated a 4 MWh ThermalBattery™ into the steam grid at a production facility in Porsgrunn, Norway. The system provides increased flexibility at the plant by balancing local steam production and reducing the amount of dumped excess steam and improving total energy efficiency.

Avery Dennison tape production
Avery Dennison, a global materials science company specialising in labelling and functional materials, last year announced it was switching from natural gas to concentrated solar thermal (CST) platform for green steam production at a tape factory in Turnhout, Belgium. The CST plant, the largest in Europe for industrial heat, uses oil as a heat transfer fluid and an EnergyNest ThermalBattery™ for storage.

The setup aims to help Avery Dennison cut natural gas consumption by 75 percent and reduce plant emissions by 70 percent as part of plans to hit net zero by 2050. "We view the Turnhout platform as the next logical step in reducing carbon use and boosting sustainability," says Claudius Gosse, senior plant manager at the facility. "The installation has earned an enthusiastic buy-in from many stakeholders, including the local community."[vii]

Eni oil treatment plan

The Italian oil and gas company Eni is pioneering the use of CSP to produce steam for oil refining. The company uses a ThermalBattery™ to extend the hours of steam production beyond daytime, reducing fossil fuel consumption across oil treatment and refinery assets and contributing to Eni's objective of reaching net zero emissions in its upstream business by 2030.

Masdar pilot

In 2015, EnergyNest installed and commissioned a ThermalBattery™ pilot with a 1 megawatt-hour (MWh) capacity at the Masdar Institute Solar Platform in Abu Dhabi, United Arab Emirates. The demonstration plant was used to measure the Thermal Battery system's long-term performance and confirmed there was no loss in capacity.

Thermal energy storage for green heat

Thermal storage is emerging in terms of market penetration but is mostly based on mature technology components and well-known physical processes. The technology has already seen widespread deployment within the CSP industry, where heat from the sun is used to warm tanks of molten salt.

Standalone molten salt storage plants have been mooted for locations that lack enough direct sunshine for CSP, although in practice a range of heat-preserving substrates can be used for thermal storage. EnergyNest, for example, uses a steel and concrete mix called Heatcrete©, which can be manufactured at low cost and has excellent thermal properties.

EnergyNest's ThermalBattery™ system is modular, scalable and purpose-built for industrial applications.

It is made from abundant, recyclable and non-hazardous geomaterials that are easy to acquire, which means local workforces and materials can be used for its manufacture and transportation can be kept to a minimum. The technology behind the ThermalBattery™ system is proven, with verifiable performance, and allows for the construction of compact storage systems with high energy density and low losses. The product's thermal storage capacity can range from megawatt-hours to gigawatt hours.

EnergyNest's ThermalBattery™ can address a range of industrial applications, as show below.

Application	Conversion	Industries	Benefits
Electrification	Electricity to steam or thermal oil	All industries; chemicals, paper & pup, food and beverages, textiles, thermal power plants (replacing auxiliary boilers), power generation (combined cycle gas)	Provision of high-grade, low-carbon steam (saturated or superheated), or thermal oil to all industrial processes for manufacturing or batch processes. Ability to exploit low-cost electricity to reduce energy costs and dependency on natural gas
Waste heat recovery	Waste heat to process heat or electricity	Metallurgy, chemicals, cement, petrochemicals	Recovery of variable waste heat sources in energy-intensive industries. Balancing of energy supplies through time-shifted delivery of heat or electricity
Steam grid balancing	Steam to steam	Pulp and paper, chemicals	Direct integration of excess steam into industrial processes. Avoidance of valuable steam dumping or back cooling. Optimisation of combined heat and power plants
Flexible power generation	Steam to electricity	Conventional, biomass, combined cycle gas turbine or waste-to-energy generation, and all kinds of steam-based power plants or cogeneration plants	Enhanced ramping ability and reduced minimum and increased maximum output in must-run plants. De-coupling of electricity production and steam provision to industrial customers in cogeneration plants
CSP / CST generation	Solar power / Solar thermal to electricity and process heat, and steam	CSP / CST	Lower capital and operating expenditure than traditional storage media such as molten salt, or oil tanks. Low complexity allows fully automated and unmanned facilities.

The ThermalBattery™ "works in the sweet spot between 150 and 400 degrees Celsius," says EnergyNest's chief executive officer, Christian Thiel. "For steam in that range, plus or minus, this is where our technology really shines. We've found a good balance of keeping costs very low for our storage, because that is really what will drive adoption for systems at pace and scale by serving a large pool of industrial applications that require steam."

This cost advantage could see thermal energy storage overtake other decarbonisation options for industrial applications that do not require extreme temperatures, Thiel believes. "I'm a big fan of hydrogen and it's important for our future," he says. "It's had an effective lobby for a long time now, but we better consider twice before burning hydrogen as a fuel because of efficiency and cost reasons."

Part of the financial attraction of thermal storage is that it can take advantage of off-peak electricity for green heat production. Another big advantage of the ThermalBattery™ concept over other forms of (thermal) energy storage is that it can run off waste heat from existing industrial processes for later downstream use. This area has "huge potential," says Ashcroft at Carbon Trust, "however, the capture and use of waste heat is currently underutilised."

Outlook and conclusions

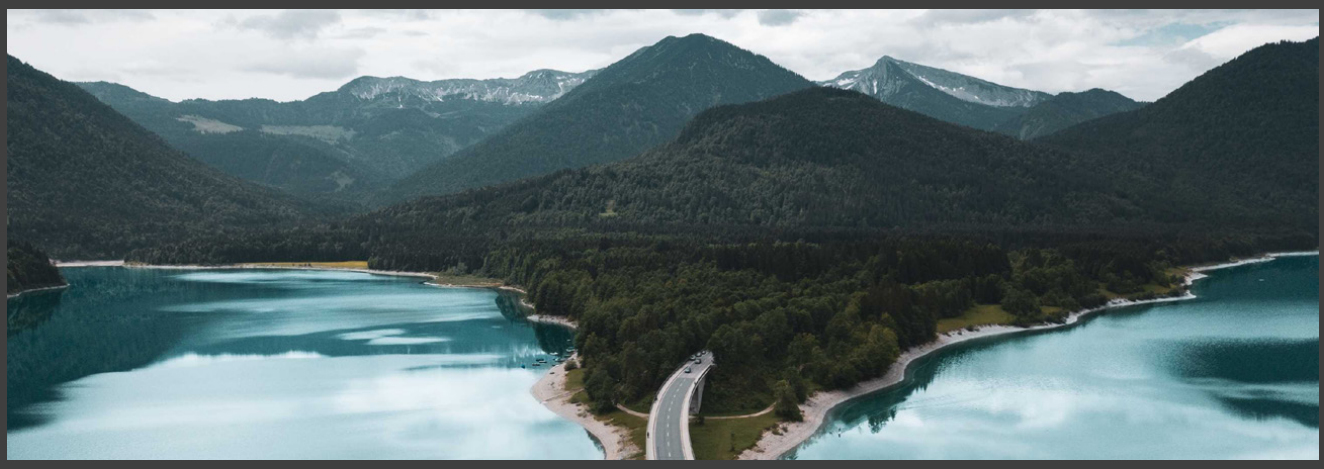
In addition to the natural fit between thermal energy storage and many industrial processes, EnergyNest has developed a novel commercial model which avoids customers having to assume any capital cost of the ThermalBattery™ acquisition. Instead, EnergyNest can build, operate and own the ThermalBattery™ system in exchange for an offtake agreement from the industrial user, e.g. in the form of a 24/7 green heat power purchase agreement (PPA).

Thanks to the efficiency of the ThermalBattery™ system, the agreement usually lets the customer acquire process heat at a significant discount compared to using fossil fuels. Beyond thermal energy storage's decarbonisation potential, and very strong contribution to customers' ESG target fulfilment, it is expected that the cost savings and/or additional revenue stream that can be accrued through Thermal Batteries will make the concept highly attractive to industrial applications, particularly as fossil fuels experience significant price increases and supply shortages.

In May 2022, for example, natural gas futures linked to the Dutch Title Transfer Facility, a leading European benchmark price, hovered around the €100 per-MWh after having topped €225 earlier in the year. This was after years of trading at less than €25 per MWh.[viii] If natural gas prices stay for long at current levels, thermal energy storage could be worth deploying merely for its fossil fuel savings potential. High gas prices look set to remain for some time, according to a short-term energy outlook from the U.S. Energy Information Administration.

U.S. natural gas inventories are already 9 percent above their five-year average and "a hotter-than-normal summer that results in high electricity demand could cause inventories to be lower than forecast and result in prices that are higher than forecast," the Administration said.[ix]

Industrial heat users surveying this outlook should be aware that thermal storage offers an immediate, reliable and cost-effective way of avoiding the growing challenges associated with fossil fuels while contributing to a faster energy transition.



Resources

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