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Hot rocks could increase duration of thermal storage solutions

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The Antora thermal energy storage battery uses graphite as a heat storage material with temperatures reaching 1,800°C

Photo: Antora

Thermal energy storage (TES) can play a key role in decarbonising hard-to-abate industry sectors – those that, typically, depend upon high temperature heat. *New Energy World* Features Editor Brian Davis looks at its potential.

The International Energy Agency (IEA) estimates that ‘hard-to-abate’ sectors account for about a quarter of global CO_2 emissions. However, new developments in TES could be used for decarbonising heavy industries where there is a need to use high temperatures – over 1,000°C, replacing fossil fuels such as natural gas and coal. What’s more, lower temperature heat storage could be used for applications such as paper and glass production, as well as in district heating.

TES systems can utilise renewable power from wind and solar farms, for example, at lower cost than fossil fuels, and store the heat using a range of materials with good thermal properties.

‘This is not a new concept,’ explains Selene Law, Senior Associate, Energy & Power at the Cleantech Group. ‘Systems of concentrated solar power which radiate heat to a receiver that uses molten salts [as a heat transfer fluid] have existed for decades to transport and store electricity.’ Currently, about 6.8 GW of molten salt capacity is installed worldwide, according to Universal Data Solutions, and the global molten salt TES market is expected to grow at a compound annual growth rate (CAGR) of about 6% during this decade.

What’s new?

Several interesting new developments are underway. Researchers and

developers are experimenting with new materials such as graphite, silicon and refractory bricks for thermal energy storage.

California-based start-up Antora Energy uses solid carbon as a heat storage material in a modular insulated system with temperatures reaching above 1,800°C – hotter than the melting point of steel. The Antora system uses renewable electricity to heat blocks of solid carbon (graphite) to reach high temperatures in an insulated thermal battery module. ‘The stored heat is then delivered at the scale and temperatures that large industrial operations – such as cement and steel – demand, or as electricity, at costs competitive with fossil fuels,’ explains Antora spokesperson Ry Storey-Fisher.

Antora’s thermal battery can output electricity at ‘breakthrough efficiencies’ using proprietary heat-to-power ‘thermophotovoltaic’ (TPV) technology, which converts the stored heat directly to electricity, with no moving parts. The thermal battery can output 24/7 heat for a decades-long lifespan and has demonstrated heat-to-electricity conversion efficiencies higher than 40%, says the company. A dedicated TPV cell manufacturing line has been set up in Sunnyvale.

Antora raised $80mn in public and private funding from investors including Bill Gates’ Breakthrough Energy Ventures and Shell Ventures, and also acquired Medley Thermal, a software company specialising in renewable power-to-heat systems. A pilot plant is operational at an industrial facility near Fresno, California, US.

The company’s main competitor is another California-based startup called Rondo Energy that uses a refractory brick, claimed to be cheaper than graphite by weight but not as energy rich. Rondo secured $60mn from Microsoft’s Climate Innovation Fund, SABIC and other investors. Its first battery is producing power for an ethanol plant in California.

The Rondo system heats the bricks directly using infrared from heating elements like those in a toaster or oven, to turn power into high temperature heat. Thermal radiation warms bricks up to 1,500°C, storing energy for hours or days with less than 1% heat loss. Heat is delivered as superheated steam via automated artificial intelligence (AI) controls to any industrial process 24/7. The Rondo heat battery can operate as a combined heat and power (CHP) system to deliver heat and baseload electricity, claims the company.

In 2023, the company supplied Siam Cement Group heat battery storage production capacity of 2.4 GWh/y, with plans to reach 90 GWh/y, which would save 12mn t/y of CO_2 emissions. 'The Rondo system can store energy at half the cost of other technologies such as green hydrogen and chemical batteries,' claims John O'Donnell, CEO of Rondo.

Massive market potential

Electrification of industrial heat has been called 'the next half trillion-dollar market within a decade' by BloombergNEF and others. Recent studies claim that the decarbonised world will need twice as much heat battery storage as grid battery storage and will greatly reduce energy costs to produce many key commodities in coming years.

According to the ***Net-zero heat*** **report** by the Long Duration Energy Storage Council and McKinsey, 2–8 TW of long duration energy storage (LDES) capacity could be deployed with cumulative capex investments of $1.7–6tn by 2040.

Different approaches

Meanwhile, Kraftblock and Alumina Energy use different ceramic alloys to reach temperatures of 1,300–1,600°C. And the US Massachusetts Institute of Technology (MIT) spin-out Electrified Thermal Solutions (ETS) claims to reach heat of up to 1,800°C using bricks, but its system is at an early stage of development.

Kraftblock has raised $20mn from six investors led by Shell Ventures. ‘Thermal energy accounts for more than half of the energy consumed in the industrial sector. TES has huge potential as a cheaper alternative to green hydrogen, for example, in the thermal sector,’ remarks Kraftblock CEO Martin Schichtel.

The company is developing a 150 MWh thermal storage facility for Pepsico in The Netherlands, in partnership with utility Eneco, to replace a 25 MW gas boiler in a crisp-making process. The system will integrate renewable energy from a wind farm into its Broek op Langedijk plant where it makes Cheetos crisps. The first phase has a thermal energy capacity of 70 MWh, with plans to raise capacity to 150 MWh, boosting emissions reduction from 51% to 98%.

The novel granulate system combines heat storage material with a binder and additives, and can store temperatures up to 1,300°C for up to two weeks, to provide energy as electricity, heat, steam or cooling. The TES comes as stackable insulated modules ranging from 4–60 MWh.

Kraftblock's pilot thermal energy storage system reutilising waste heat for a kiln burning ceramics
Photo: Kraftblock

In another approach, Massachusetts-based Fourth Power recently raised $19mn from Breakthrough Energy Ventures and others to scale new thermal battery technology using liquid tin.

The technology takes grid energy – ideally from renewable sources – and fuels an industrial furnace that heats up liquid tin to 2,600°C. The tin is then moved through graphite piping, transferring heat to insulated carbon blocks that can hold heat for over a month. To convert the heat back to electricity, the piping system transfers the heat through the tin to another block, lined with tungsten and gold, which radiates bright light that is converted back to electricity using TPV cells. The system is designed for projects around 100 MW at commercial scale.

Challenges and opportunities
As a nascent technology, TES still faces multiple challenges including utility, grid operator and regulatory issues. 'One of the biggest challenges to scaling thermal energy storage deployments is access to wholesale electricity markets', Blaine Collison, Executive Director of Renewable Thermal Collaborative, told *Utility Drive* magazine.

There may also be issues around the siting of TES. 'Unlike batteries, which are located outside industrial plants, thermal energy storages are directly connected to the infrastructure inside a plant. And industry is very reluctant to integrate something new into their plant. This is a barrier that we have to overcome by building more great projects,' Kraftblock's Schichtel told *New Energy World*.

He recognises that: 'Thermal energy storage is flying under the radar and its popularity is far below its potential. There is opportunity to accelerate

decarbonisation for process heat in a much cheaper way than batteries or hydrogen.'

Thermal batteries are considered to be cost-competitive with natural gas in many parts of the US today, although the economics depend on location, electricity supply and access to wholesale power prices, notes a **report** by the Center for Climate and Energy Solutions and Renewable Thermal Collaborative.

'The biggest advantage is that thermal energy systems can grow with the grid as renewables expand,' says Arvin Ganesan, CEO of Fourth Power.

> ***'Thermal energy storage is flying under the radar and its popularity is far below its potential. There is opportunity to accelerate decarbonisation for process heat in a much cheaper way than batteries or hydrogen.' – Martin Schichtel, CEO, Kraftblock***

What's the business case for TES?

There are two key business cases for TES, suggests Kraftblock's Schichtel.

For waste heat recovery, the customer saves on fossil fuels and the payback comes largely from lower operating costs as well as savings on carbon emission taxes where they apply.

Using renewable energy, the TES not only shifts energy availability, but also shifts energy when it is cheap to cover times when energy is expensive – with TES, industries can take advantage of low or even negative energy prices.

‘For long-term storage, such as two weeks, the business case is a bit trickier. As the certainty of having energy over such a long time has a higher cost per cycle,’ Schichtel says.

Further research

Researchers at universities and national laboratories round the world are developing new high temperature materials for TES. The NREL Enduring project uses molten silicon to store up to 26 GWh of energy up to 1,200°C. The MIT Atomistic Simulation and Energy Research Group is exploring a silicon heat battery that can reach a temperature of 2,400°C, using multi-junction photovoltaics to discharge electricity. In 2021, the lab says it set a world record for a liquid-metal pump reaching 2,028°C.

TES for power

Some innovators are focused entirely on TES to store power, such as molten salt developer Malta, CO_2 battery innovator Energy Dome, and metal alloy TES company Azelio.

‘Renewable energy is stored as heat and converted back to power by using generators or heat exchangers in a heat-to-power (H2P) system when demand peaks or power prices are high’, says Cleantech Group’s Law. ‘However, compared to competing LDES technologies that can reach up to 90%, the roundtrip efficiency of the H2P process is only about 50%.’

TES is one of the few solutions available for seasonal storage that spans days or even weeks. Nevertheless, according to Law: ‘Many innovators in the TES space do not consider power markets as their primary source of revenue but are open to receiving capacity payments for *ad hoc* production as required by the transmission system operator (TSO). The problem with long duration energy storage is how do the systems make money, because when it comes to electricity there are very few business models for power storage beyond 12 hours.’

District heating

The third key application for TES batteries is district heating in the range of 500–750°C. Unlike the nascent thermal storage sector, commercial-scale TES solutions are already operating in district heating.

Finnish developer Polar Night Energy has commissioned the world's first sand-based district heating system in Kankaanpää, Finland. The 8 MWh system provides 12,500 people with heat for up to 80 hours. Another Scandinavian innovator, Hyme, is building a 1 MW/20 MWh plant on the Danish island of Bornholm, providing heat, power and ancillary services from a molten salt system.

Looking ahead

Cleantech notes that at least nine TES innovators have completed demonstration plants. 'We believe that the trickle of recent TES pilots will become a wave in 2024, with commercial scale operations likely within the next five years,' says Law. 'With very few incumbent solutions, innovations that reach high enough heat to decarbonise the hard-to-abate industries will make TES a long-duration energy storage solution.'