Heatcube®

Heating the way forward – how to effectively decarbonize industrial process heat.

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The world’s largest energy demand is for heat.

The world’s largest energy demand is for heat, primarily sourced from fossil fuels, which account for 40% of global carbon emissions.

This presents a major challenge for emission reduction and sustainable development, especially in the industrial sector, which accounts for 22% of total energy demand and is a significant CO2 emitter. The global demand for decarbonised industrial process heat is nearly 26,000 TWh annually. About 45% of this (up to 500°C) can be readily electrified today.

Industrial companies have set ambitious targets of 50 - 60%, some even 100%, emission reductions by 2030. By 2050, virtually every company aims to be net-zero.

“With substantial CO2 reductions, reasonable initial investment, and a 25-year lifespan, Heatcube offers an immediately available, cost-effective, and sustainable solution.”

Decentralized storage is a linchpin in the global strategy for decarbonization, revolutionizing the way we generate, store, and distribute energy. In the quest to mitigate climate change and transition towards a sustainable energy future, the significance of decentralized storage solutions cannot be overstated.

One of the primary drivers of the move towards decentralized storage is its pivotal role in supporting the integration of renewable energy sources. As solar and wind power continue to gain prominence, their inherent intermittency poses a challenge to maintaining a consistent power supply. Decentralized storage systems, such as thermal storage, address this challenge by capturing excess energy during peak production periods and releasing it when demand is high or renewable generation is low. This mitigates the reliance on conventional, carbon-intensive backup power sources, paving the way for a cleaner and more reliable energy grid.

But how can this be achieved?

The answer is a combination of solutions and technologies, and the electrification of process heat is one crucial part of this critical puzzle.

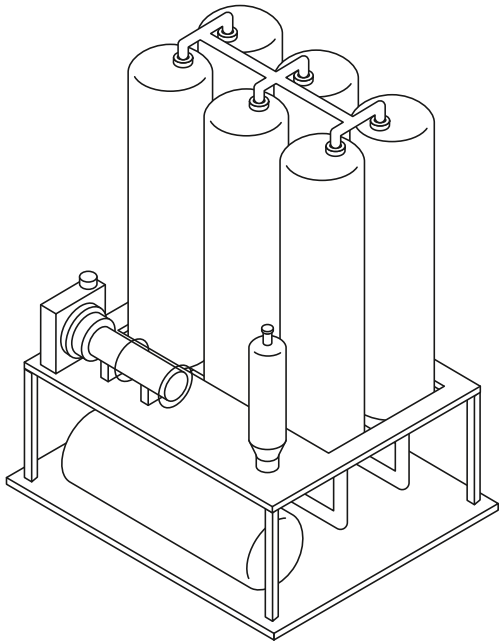
Kyoto Heatcube is a tangible solution to effectively electrify process heat in the industry. Switching to Heatcube from fossil fuels reduces CO2 emissions annually by 2,000 to 15,000 tons, depending on the type of fuel replaced (e.g., natural gas, coal, diesel). With substantial CO2 reductions, reasonable initial investment, and a 25-year lifespan, Heatcube offers an immediately available, cost-effective, and sustainable solution.

up to 15,000 Tons

Annual CO2 reduction

“Switching to Heatcube from fossil fuels reduces CO2 emissions annually by 2,000 to 15,000 tons, depending on the type of fuel replaced (e.g., natural gas, coal, diesel).”

CO2 reduction



Replacing natural gas
in the Industry with

1x 52MWh

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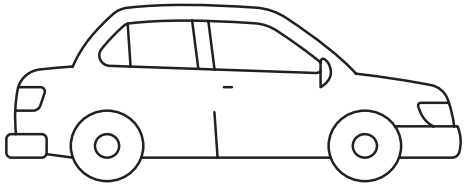


CO2 reduction
equivalent to taking

7,155

cars off the road

The Thermal Battery for our future.

Thermal Energy Storage (TES) using molten salt has been a staple technology in the Concentrated Solar Power (CSP) industry for nearly two decades.

With Heatcube, the proven TES technology is scaled down and combined with a new process design, allowing the use of the technology for industrial processes. Heatcube enhances demand flexibility by separating industrial heat demand from immediate power availability. It offers services like demand shifting, renewable energy integration, and sector integration (electricity and heating). Heatcube efficiently implements load shifting, utilizing abundant and affordable renewable energy for clean and stable process heat.

Heatcube is a highly flexible, multi-functional energy storage system designed to deliver “on-demand” heat for industrial applications. Heatcube can be tailored to optimise performance based on the required heat demand by utilising three core components for charging, storing, and discharging.

By combining proven technology with state-of-the-art design, Heatcube can provide a constant steam output between 150° C and 300° C. Kyoto’s modular approach allows solutions to be tailored to each industrial customer based on charging capacity, storage capacity, and heat generation.

Designed for Industry

Heatcube can be fully charged in hours while supplying heat for 24 hours - depending on the installed capacity and the heat capacity needed. A distinctive feature is that it can charge and discharge simultaneously, allowing the utilization of renewable energy whenever it is available without interrupting the heat supply. The short ramp time enables users to access the balancing (frequency reserve) markets.

The charging capacity is 10, 15 or 20 MW from the grid and/or off-grid renewable energy sources. The modular system of 13MWh storage capacity per tank can be expanded up to a total capacity of 104MWh. Heatcube can be adapted to cater for various heat processes with thermal duty up to 14 MW and pressures up to 25 bar.

The circulation process

Charging Heatcube:
Cold molten salt is circulated through the electrical heater and stored as hot molten salt in tanks.

Discharging Heatcube:
Hot molten salt is circulated from the tanks through the steam generator system, producing steam and returned as cold molten salt to the tanks.

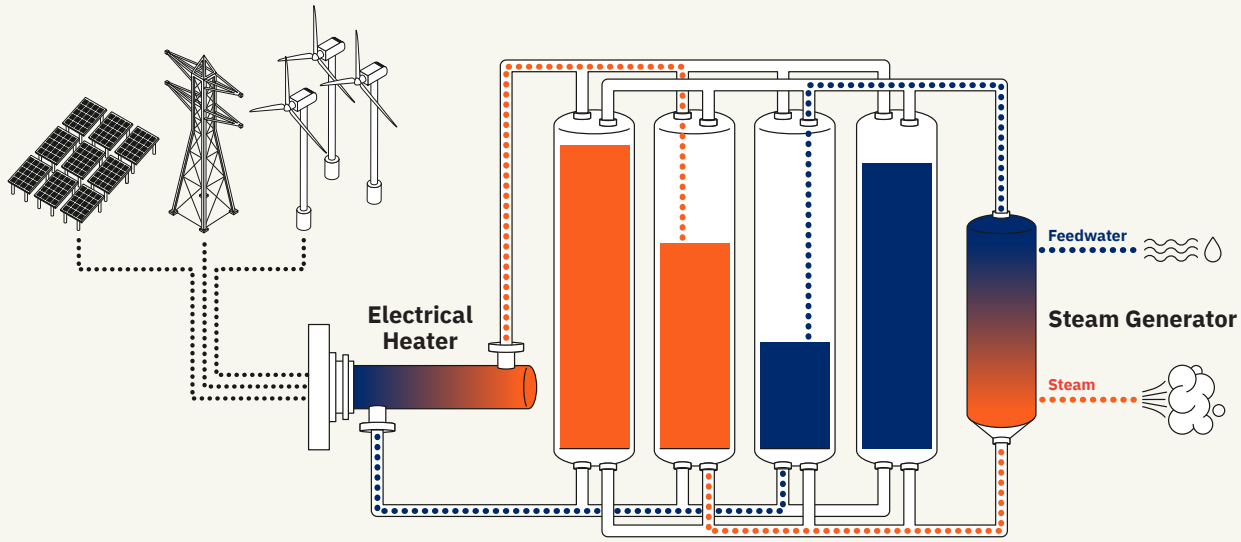


Fig. 1: *Heatcube charge and discharge process.*

“Heatcube is designed to be seamlessly integrated into an existing production process. The plug-and-play solution is simply connected to the power source, feedwater, and steam outlet.”

Operation

Heatcube operation is managed by the integrated Battery Management System (BMS).

The purpose of the BMS is to 1) gather necessary data for control, reports, statistics, and database storage and 2) operate Heatcube from a mechanical point of view in a fail-safe manner. The BMS ensures all battery operations are performed correctly and safely but relies on external systems to start and stop charging and discharging.

Simultaneous charging and discharging

The molten salt circulation system is designed to charge (electrical heating) and discharge (process heat, e.g. steam) separately; hence, the system allows for simultaneous charging and discharging of the thermal energy storage system. This enables the operator to exploit available cheap electricity anytime during the day while producing process heat.

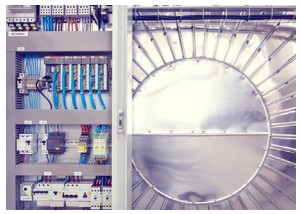
Salt as a storage medium

The most efficient use of energy when producing process heat is to store the energy as heat. Using molten salt as a storage medium brings several advantages to the industry. The ternary salt is sustainable and kept within its operating conditions, ensuring that it will not deteriorate over time. The sensible heat storage provides a stable process heat temperature and quality in the range of 150 - 300°C.

Heatcube uses no rare earth minerals. The salt mixture is neither flammable nor explosive, and the salts have been used globally across multiple energy production and storage solutions for the last decades. The salt is non-degradable, allowing for recycling and reuse in new Heatcubes.

Seamless integration

Heatcube is designed to be seamlessly integrated into an existing production process. The plug-and-play solution is simply connected to the power source, feedwater, and steam outlet.



150 - 300°C

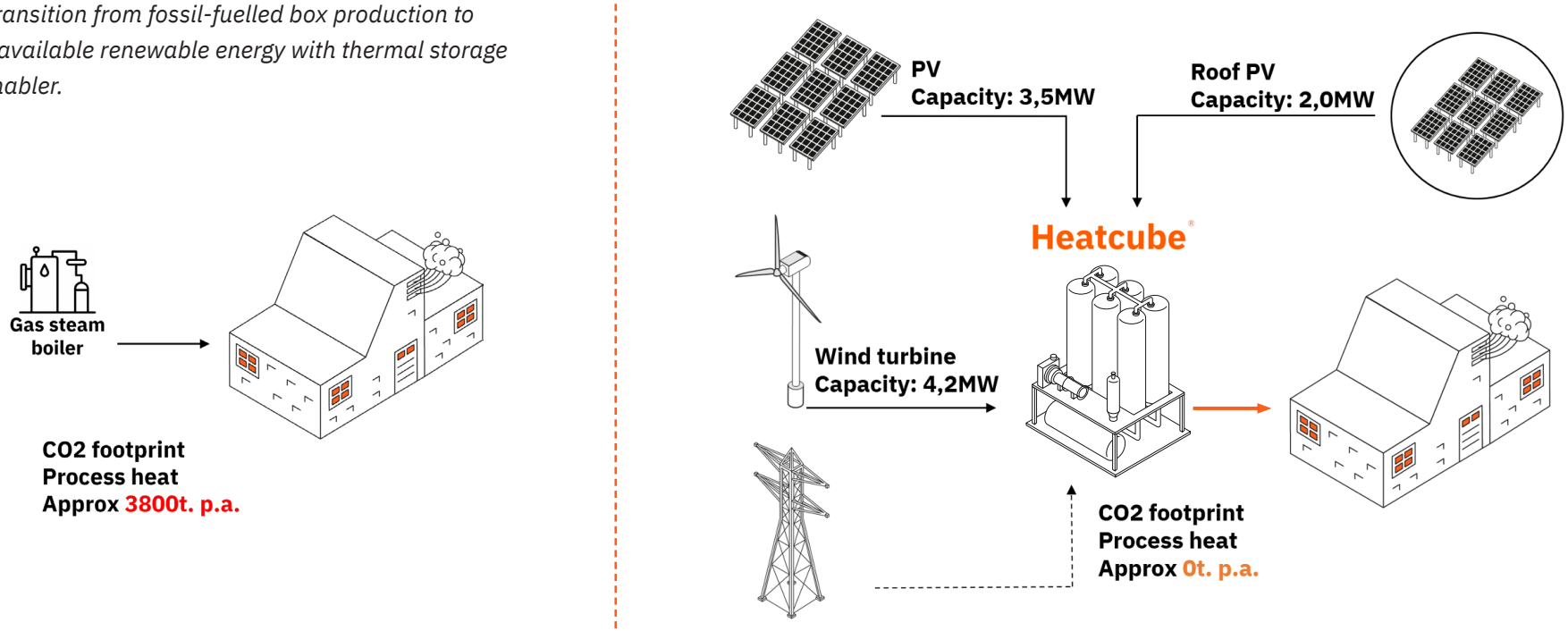
Steam temperature

“The most efficient use of energy when producing process heat is to store the energy as heat. And that is what we do with Heatcube.”

Heating the paper the world is shipped in.

75% of all transported goods are packed in corrugated cardboard. The corrugated cardboard industry uses fossil-fuelled steam for pre-heating, fluting, glueing, heating and drying in the production of boxes.

Fig. 2: Transition from fossil-fuelled box production to utilizing available renewable energy with thermal storage as the enabler.



The aggregated footprint in the industry was 11,5 million to. CO2eq. in 2020. If no actions are taken, the aggregated footprint will increase to 17,6 million to. CO2eq. in 2050. Yet, reports show that energy-related investments will increase by x4 until 2030 and more than x10 over the next decades. It is further estimated that box producers in general can produce up to 40% of needs with off-grid renewables (FEFCO Climate Neutrality Roadmap data).

In an effort to meet its ambition of 55% emission reduction by 2030, a German box producer is currently investing in expanding PV and wind energy to a total capacity of approximately 10MW. The current CO2 footprint for producing cardboard is 3800t. p.a. for one site alone. The introduction of renewables calls for storage of intermittent energy and Kyoto Heatcube serves as an enabler for creating fossil-free process steam.

Need for speed!

To meet the goals of the Paris Agreement, the global transition to clean power needs to be four to six times faster than at present, according to the International Energy Agency (IEA) and International Renewable Energy Agency (IRENA).

Heat counts for the largest energy demand globally, and it is almost entirely produced by fossil fuels today (89%). Major efforts are invested in providing the industry with fossil-free alternatives, including hydrogen. Hydrogen will probably be a part of a solution in the long term, but presents economic, technical, and infrastructural challenges, especially for temperatures and volumes in most industry processes.

To match the industry´s ambitions, action is required! Technologies are already available to electrify a significant portion of that demand and produce industrial heat from cheap renewable energy. Electrifying process heat is considered a low-hanging fruit as there are available and scalable solutions today.

And it is worth remembering that 2030 will be only 72 months ahead when 2024 breaks.

Fig. 3: *Heatcube at Norbis Park has replaced coal for district heating in Aalborg, Denmark. It is charged with 5MW and has a storage capacity of 18 MWh. This Heatcube reduces emissions up to 2000 tonnes of CO2 per year.*

Electrification - demonstrated

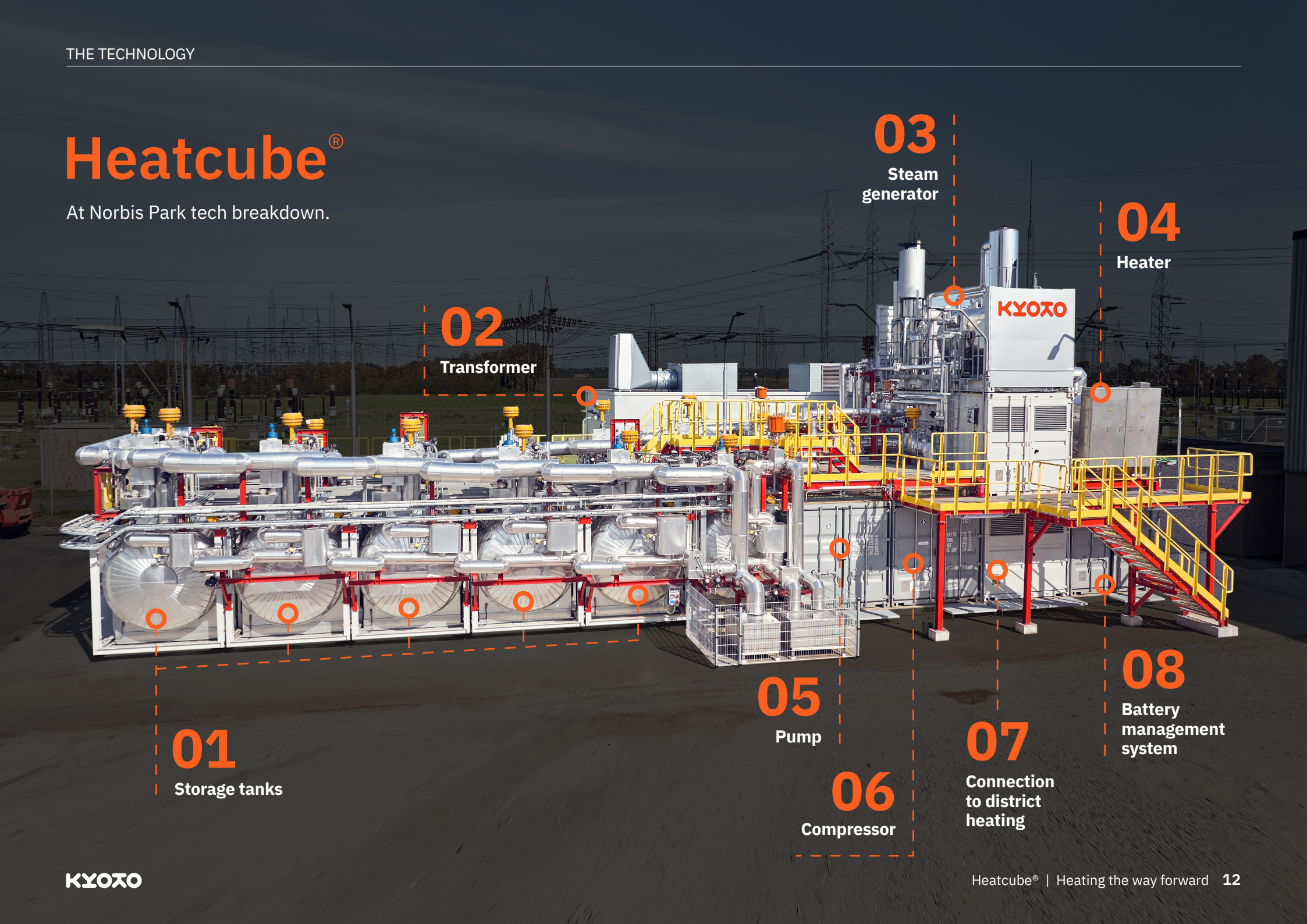
The first installation at Nordjylland Power Station in Aalborg, Denmark, marks the world's first molten salt technology for storage and heat production in connection with the district heating network.

This Heatcube replaces coal-generated district heating with heat produced from renewable electricity and/or electricity sourced from the grid, significantly reducing CO2 emissions.

Heatcube will also enable Aalborg Forsyning to utilize it as a balancing asset on the grid within the flexibility market.

Heatcube®

At Norbis Park tech breakdown.



Why is decentralized thermal storage a key to decarbonization?

Network congestion in Europe has become a pressing issue due to the rapid growth of renewable energy sources. The intermittent nature of renewables, coupled with inadequate grid infrastructure, leads to congestion.

This hampers efficient energy transmission, resulting in bottlenecks, increased curtailment of renewable energy, and challenges in balancing supply and demand across the continent.

Local thermal storage, such as Kyoto Heatcube, aids grid balance by storing excess renewable energy during periods of high generation. When demand peaks or renewable output is low, stored thermal energy is released, providing a flexible and reliable energy source. This helps stabilize the grid, mitigates imbalances, and enhances overall grid resilience.

Scope 1 & 2 and Scope 3

Scope 1 and 2 decarbonization efforts are vital for reducing direct and indirect greenhouse gas emissions. **Scope 1** addresses direct emissions from owned or controlled sources, requiring businesses to minimize fossil fuel use. **Scope 2** tackles indirect emissions from purchased energy, emphasizing a shift to renewable sources and energy efficiency to achieve comprehensive decarbonization. Most businesses have defined targets of 50 - 60 % emission reduction by 2030 and net-zero by 2050. **Scope 3** encompasses indirect emissions from a company's value chain, including suppliers, customers, and product life cycles.

Addressing Scope 3 emissions is becoming essential for comprehensive corporate decarbonization strategies. Amazon is an example that puts its entire supply chain on notice: Starting in 2024, Amazon will update its supply chain standards "to require regular reporting and emissions goal setting." Amazon hopes to use its size and scale to "benefit businesses that are committed to decarbonizing" and provide "products and tools to both track emissions and help decrease them." According to Amazon, it will "help select suppliers" transition to using carbon-free electricity. This practice has also been embraced by companies such as Walmart and Apple.

Scope 3 will play an increasingly significant role as Scope 3 reflects a company's indirect emissions and thereby affects its attractiveness to investors. Investors increasingly value companies with comprehensive emission reduction strategies, emphasizing sustainability and long-term environmental responsibility.

Thermal storage as a balancing asset

Decentralized thermal batteries can participate in frequency response markets, providing grid services and earning revenue for their operators. This can create new opportunities for decentralized energy

storage systems to contribute to grid reliability and receive compensation for their services.

Heatcube offers advantages such as fast response times, improved grid stability, flexibility, and the ability to integrate with local renewable energy generation, making it a valuable asset in the AFRR and MFRR markets. By responding rapidly to frequency fluctuations, Heatcube contributes to grid stability and helps prevent imbalances in the grid.

Energinet, the independent public enterprise owned by the Danish Ministry of Climate, Energy & Utilities responsible for owning, operating, and developing the electricity transmission system in Denmark, has approved Heatcube as a provider of flexibility services for the DK1 grid area.

Recent response time tests have confirmed Heatcube's exceptional operational performance, demonstrating a seamless and reliable ramp-up of the heater from 0MW to 5MW in under three seconds. This rapid response time exceeds the requirements for all flexibility markets.

The graph is a visual representation of the test results.

AI-supported trading systems, exemplified by platforms like Enspired, contribute to the optimization of thermal storage batteries, leading to lower energy prices for industrial companies. These

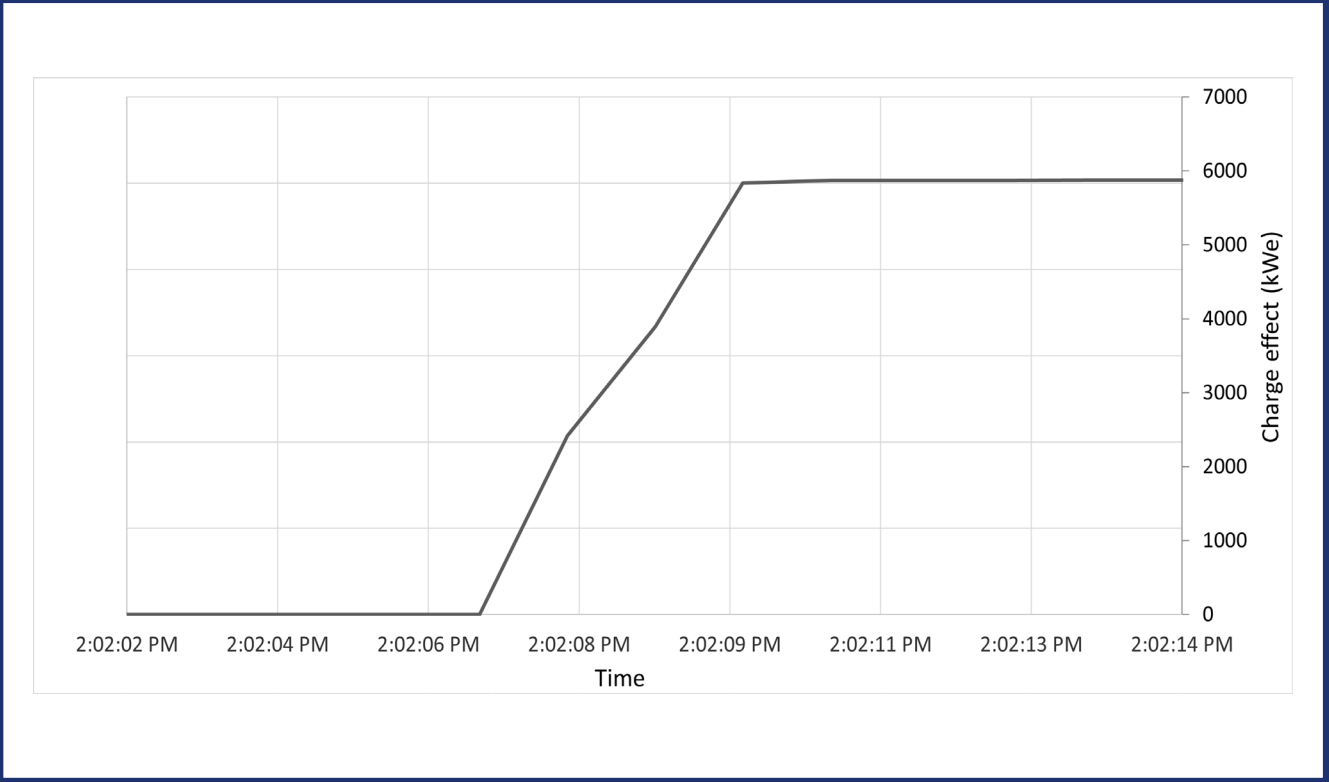


Fig. 4: Visual representation of the ramp-up test results.

systems harness the power of artificial intelligence to analyze diverse datasets, including market trends, weather forecasts, and energy demand patterns. By accurately predicting peak demand periods and market fluctuations, AI-supported algorithms enable precise optimization of thermal storage batteries.

The key advantage lies in strategically charging these batteries during off-peak hours when energy prices are lower, and demand is minimal. During periods of high demand, the stored energy is then efficiently released, mitigating the need for expensive energy sources.

Digitization with Kyoto

Digitizing thermal storage provides a transformative edge by introducing real-time monitoring and control to energy management.

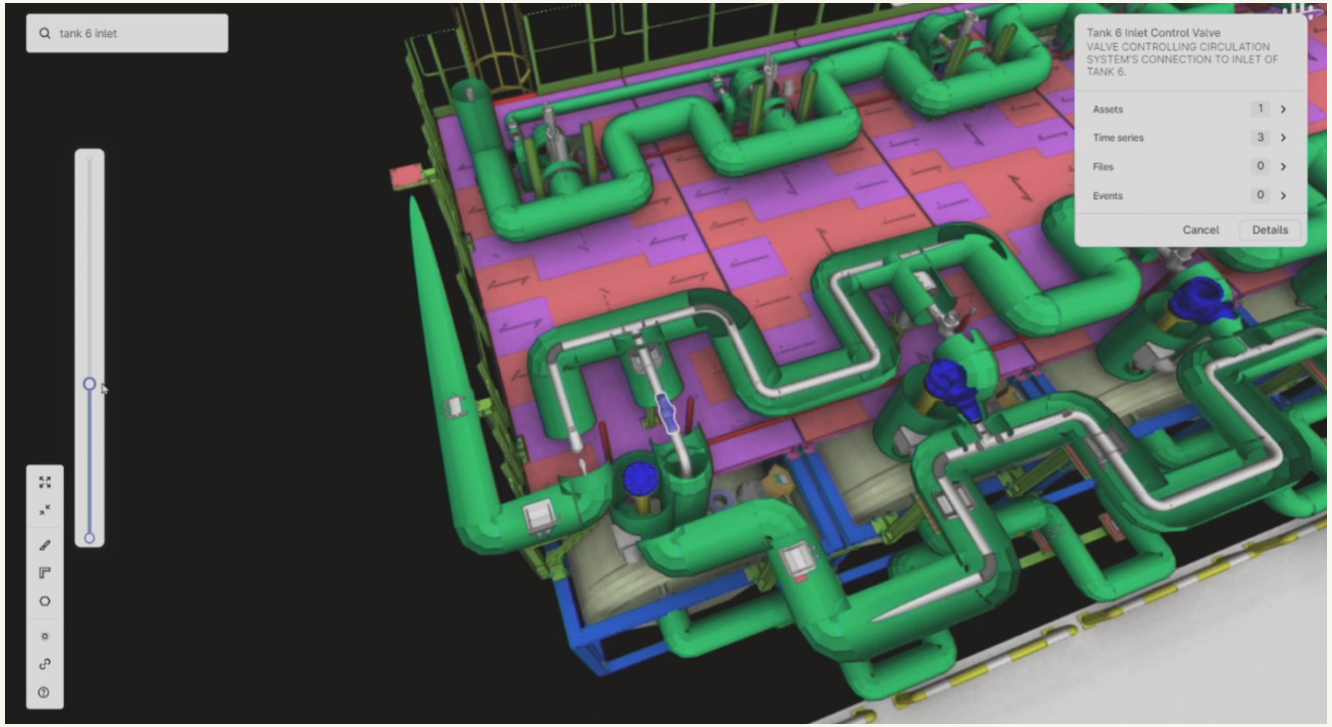


Fig. 5: *Heatcube Digital Twin at Norbis Park in Aalborg, Denmark.*

Smart technologies enable precise optimization of heat storage, allowing for demand response and integration with variable renewable sources. Predictive analytics enhance system efficiency and reliability, minimizing downtime through proactive maintenance.

This digital integration fosters a more resilient and responsive energy infrastructure, reducing operational costs and environmental impacts. Additionally, the seamless interaction with smart grids promotes grid stability and facilitates the transition to a sustainable, decentralized energy landscape, marking a crucial step towards a more efficient and low-carbon future.

It positions Heatcube with capabilities to easily integrate with emerging power market players, offering flexibility and potentially new revenue streams for industrial plant owners. Furthermore, the integration will empower Kyoto customers to streamline data management and cost-optimize operations, enabled by a foundation of best-in-class preventive and predictive maintenance.

Conclusion

Kyoto Heatcube represents a tangible solution for the electrification of industrial process heat. Its demonstrated ability to effectively replace fossil fuels using renewable energy sources provides the industry with a concrete solution to meet the emission targets for 2030 and beyond.

Its modularity, scalability, and industry-specific plug-and-play design match the various process needs of most industrial companies requiring process heat. The proven molten salt technology additionally provides great flexibility, both when it comes to exploiting renewable energy when available and simultaneously producing heat, as well as allocating thermal storage as an asset in the balancing market.

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Does it pay off to switch to renewable heat?

Find out how much you can save with Kyoto. Visit our commercial page.