Thermal Energy Storage Handbook

Technology provider and reference projects for industrial process heat

Welcome

Industrial thermal energy storage has moved beyond the stage of conceptual design. Across the world, a wide range of technologies is already being deployed in real industrial environments – supplying process heat for everyday products such as food and paper, stabilizing energy systems and enabling the large-scale integration of renewable energy without compromising operational reliability or productivity. These applications demonstrate clearly that thermal energy storage is no longer a promise for the future, but a practical and available solution today.

At the same time, the market for thermal energy storage is still at an early stage. While European and national policy frameworks increasingly recognise the potential of renewable and electrified heat-supported, for example, through the European heat auctions or the German BIK Funding programme – many industrial end-users remain uncertain about which storage technologies are suitable for their specific applications, how these systems can be effectively integrated into existing processes and what performance can realistically be expected.

This handbook is intended to address these questions. It provides an overview of proven thermal energy storage solutions and compiles storage projects that are already operating or being implemented in real-world applications. The showcased projects demonstrate tangible benefits, including CO_2 emission reductions, improved system flexibility and a reduced reliance on imported fossil fuels.

At the German Aerospace Center (DLR), thermal energy storage has been a core research topic for more than three decades. Developing this handbook is part of our effort to advance storage-supported heating solutions: by sharing independent technical knowledge, system-level insights and practical experience from applied research, we aim to support both industrial end-users and technology providers in the successful implementation and further development of thermal energy storage under real operating conditions.

We hope that this handbook will serve as a useful reference for industry, research and decision-makers and that it will stimulate collaboration in further advancing industrial thermal energy storage as a key element of a sustainable energy system.

Prof. Annelies Vandersickel
Department of Thermal Process Technology
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German Aerospace Center (DLR)

Preface

Thermal energy storage is a key enabling technology for the decarbonisation of industrial heat supply. By decoupling heat generation from heat demand, it enables the efficient use of renewable electricity and waste heat, increases system flexibility and supports reliable industrial operation under changing energy system conditions.

The thermal energy storage landscape is evolving rapidly. A wide range of storage concepts is currently being developed, targeting improvements such as lower costs, better temperature matching to industrial processes and increased system lifetime. At the same time, the number of technology providers entering the market is growing, reflecting both rising demand and increasing technological maturity. This dynamic development makes it increasingly challenging for industrial stakeholders to maintain an overview of available solutions and their practical applicability.

This handbook brings together contributions from a broad range of providers to illustrate the current state of industrial thermal energy storage and the diversity of available approaches. It covers different storage principles, temperature ranges and integration concepts and presents real-life projects in which thermal energy storage is used to supply process heat, integrate renewable energy sources, utilise waste heat and increase operational flexibility.

The focus of this booklet is on high-temperature, industrial-scale thermal energy storage systems that are commercially available or close to market entry, with particular emphasis on systems that have been implemented under real operating conditions. While this provides a solid snapshot of the current market, the overview is not intended to be comprehensive and does not cover all technologies or providers.

Aim of this handbook

Overall, this handbook aims to facilitate the uptake of thermal energy storage in industrial applications by improving transparency and orientation in a rapidly developing market. In particular, it seeks to:

- provide a structured overview of commercially available high-temperature thermal energy storage technologies and key market actors,
- support early-stage planning and technology selection for industrial decarbonisation projects,
- highlight key drivers and benefits for thermal energy storage implementation, including integration concepts, operational advantages and emerging business models.

DLR competences

The German Aerospace Center (DLR) is a national research institution with longstanding expertise in energy, transport, space and security. At the Institute of Engineering Thermodynamics, we focus on applied research delivering real-world solutions for sustainable heat supply and storage. With more than 30 years of experience in the development and integration of thermal energy storage systems, we contribute to accelerating innovation by addressing key challenges at material, component, system and integration levels.

To reflect the wide diversity in the heating sector, the department's technology portfolio spans a broad temperature range – from low-temperature district heating to high- and ultra-high-temperature industrial processes. Our portfolio includes molten salt, solid media and thermochemical energy storage systems, complemented by electrical heaters, heat pumps and advanced heat management solutions. By combining deep material expertise with experimentally validated models and pilot-scale demonstration, we push current technologies toward higher temperatures, increased energy density and reduced costs.

A key strength of DLR lies in its extensive small- and large-scale test infrastructure, which enables proof-of-concept and operation under industry relevant conditions. This infrastructure allows new technologies to be de-risked prior to large-scale deployment and supports the optimisation of existing solutions already on the market.

Through close collaboration with industry, startups and technology providers, DLR supports the implementation of thermal storage systems into real processes and infrastructures. By bridging the gap between research and application, the institute contributes to improving performance, durability, cost efficiency and system integration – strengthening the role of thermal energy storage as a reliable cornerstone of the energy transition.

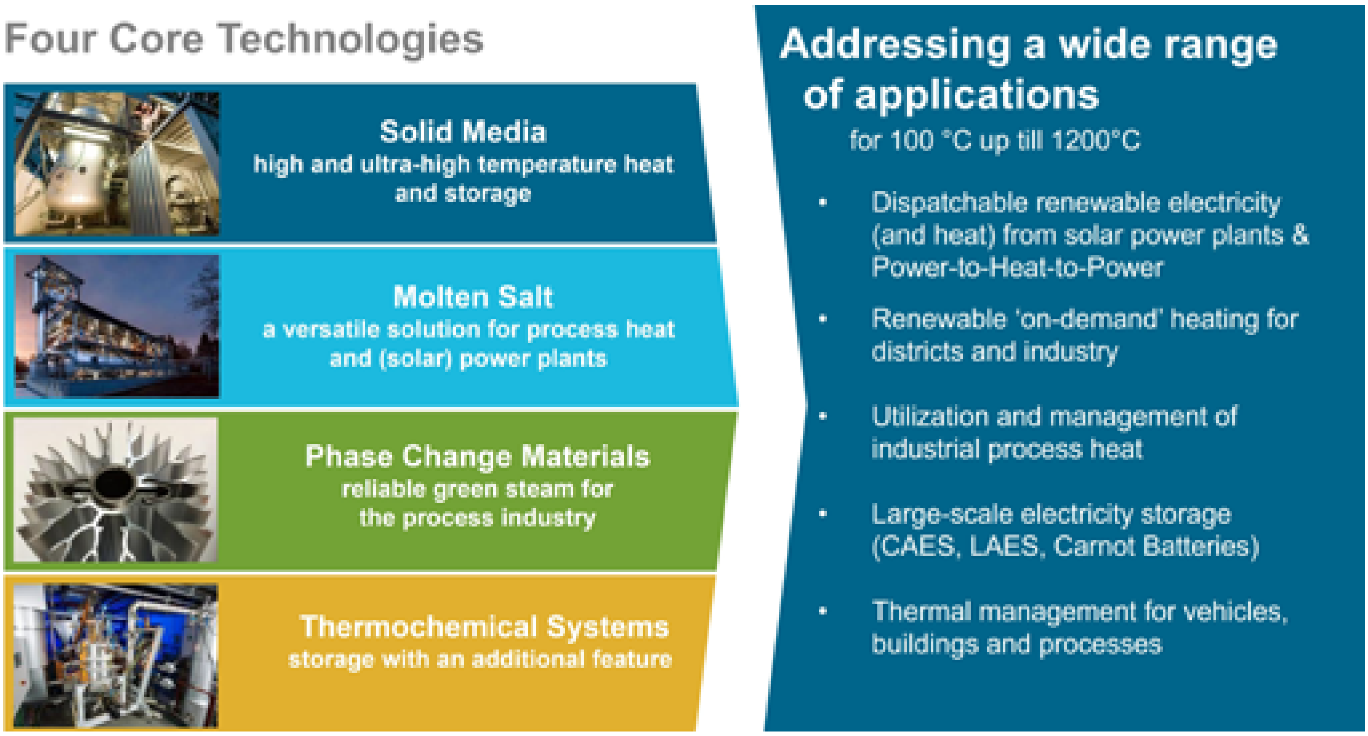
In short, DLR offers:

For technology providers:

- support in technology development and optimisation along the entire innovation chain, based on in-depth scientific and engineering expertise,
- access to testing and qualification at relevant scale to de-risk components and validate system performance.

For industrial end-users:

- independent technical expertise and advanced modelling tools to support the development of decarbonisation concepts,
- supplier-neutral assessment of integration concepts, including support in tender preparation and evaluation,
- advanced simulation models and digital twins to optimise operation for specific industrial use cases.



DLR projects

Ultra high temperature air heater

Industries requiring process heat well above 1,000 °C are a key challenge for decarbonisation. To address this need, high-temperature Power-to-Heat solutions are developed and tested, including compact induction heating systems that convert electrical energy into high-temperature heat with high efficiency and power density. These systems are designed to meet strict requirements in terms of performance, cost-effectiveness and industrial robustness, making them a viable retrofit option for replacing fossil-fired burners. By focusing on high conversion efficiency (> 90 %) and scalable induction heating technology, sustainable electrification of industrial heat supply is enabled, accelerating the heat transition across multiple application domains.

Project: KEINER

CO2 neutral electrical steam generation with latent heat storage

Steam is a critical process energy carrier in many industries, traditionally supplied by fossil gas. In the PCM-Grid project an electric steam generator with a storage function of 3 MWh is being developed and integrated into the industrial process of an end customer. This is based on the finned tube latent heat storage concept developed jointly by DLR and KI-Alu. To charge the storage, a suitable phase change material is melted at high temperatures using electrical heaters. During discharging, the phase change material solidifies and process steam is provided to an industrial process. This approach decouples steam generation from volatile electricity availability and enables CO_2-neutral industrial steam supply with high flexibility and reliability.

Project: PCM Grid
Project consortium: Viessmann Industriekessel Mittenwalde GmbH, RuLa-BRW GmbH, IFAM

Zero emission chemical site

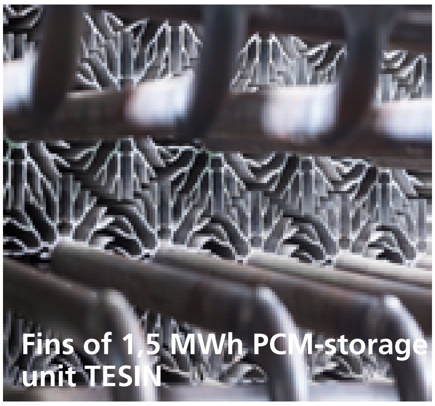
The chemical industry is adopting increasingly ambitious greenhouse gas emission targets, driving the need for scalable decarbonization concepts. This research examines a utility system for chemical sites based on renewable power purchase agreements and green hydrogen, complemented by a molten salt thermal energy storage system. Thermal energy storage enables efficient integration of photovoltaic and wind power, reducing overall system costs by up to 27 % while significantly increasing resilience against fluctuations in hydrogen prices. At the same time, the approach achieves maximum renewable integration, covering up to 85 % of the total energy demand.

Project: TransTESChem
Partner: Currenta GmbH & Co, Covestro Deutschland AG, TSK FLAGSOL Engineering GmbH, Gesellschaft zur Förderung Angewandter Informatik e. V, JPM GmbH


Basalt bulk material for liqud salt in a single-tank storage


Sensible media storage in HOTREG test bed

PCM storage system of CHESTER Carnot Battery


Fins of 1,5 MWh PCM-storage unit TESIN


Solidified storage salt

Direct steam generation with PCM and fins

Limestone storage

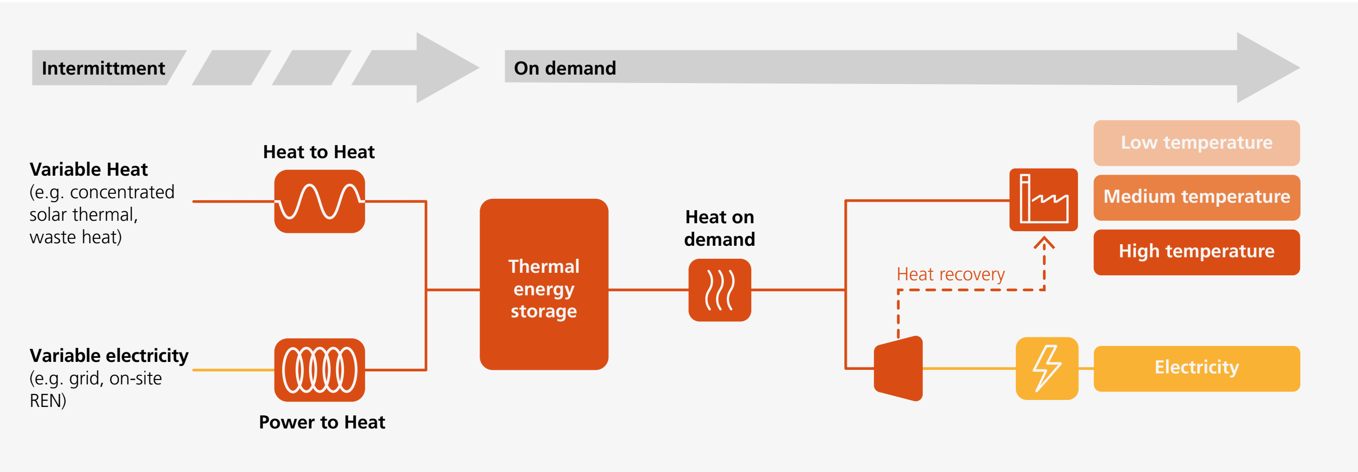
Molten salt storage TESIS'test section

Section 1: Role & business models

© Kyoto Group

Role of thermal energy storage

Storing heat with Thermal Energy Storage (TES) solutions allows intermittent renewable energy or waste heat streams to be used on-demand. TES can be charged either directly with heat e.g. from solar thermal plants or waste heat (heat-to-heat), as well as electrically using e.g. heat pumps or resistive heating (power-to-heat). The heat is then stored cost-effectively in widely available storage media such as water, molten salts, rocks, so-called phase-change materials or even thermochemical materials and discharged when heat is required. Depending on the individual demand and electricity market design, the system can furthermore be combined with a power cycle to generate electricity in addition to heat.



Thermal energy storage (TES) use in industry; adapted from Future Cleantech Architects.

User benefits of TES integration:

On-demand renewable heat supply
TES bridges the gap between fluctuating renewable heat supply and heat demand by storing excess heat and releasing it when required. TES integration thus ensures reliable heat delivery on demand and enables the integration of larger shares of renewable energy such as on-site PV or electricity from Power Purchase Agreements (PPAs). A wide range of storage technologies enables TES at the required temperature, from high-temperature heat to cold storage, while a variety of media can be used to discharge the storage, such as steam, hot air or oil, simplifying integration into existing infrastructures.

Waste heat recovery reducing operating costs:
Utilization of industrial surplus heat allows companies to capture and store otherwise wasted energy for later use or sale. This reduces energy demand and lowers operational costs.

Emission reduction and reduced fuel dependency
TES integration reduces CO_2-emissions by replacing fossil-based heat and improving renewable energy and waste heat utilization. It furthermore reduces the reliance on volatile fossil fuel markets, enhancing energy security.

Reduced need for back-up generation
TES serves as a backup thermal heat supply and can ensure reliable energy delivery in case of failure of other heating systems and can enable fast black-start capabilities. Its quick response and high reliability reduce dependence on conventional gas boiler operation.

Business models:

Asset Ownership
A company owns and operates the TES as part of its heating/cooling infrastructure and benefits directly from energy and cost savings.

Heat-as-a-Service (HaaS)
The customers pay for delivered heat rather than owning heating equipment, while the provider installs, operates and maintains the system. TES integration allows providers to optimize energy use, cut costs and deliver reliable heat on demand, while industrial users get access to low-carbon heat without upfront investment.

Heat Purchase Agreement (HPA)
A long-term contract, in which a customer agrees to buy a specified amount of heat (in MWh or GJ) from a provider at a pre-agreed price. By integrating the TES, the provider can again optimize energy use and cut costs.

The Power-to-Heat opportunity

While TES is instrumental in supplying reliable, low carbon heat for industrial processes, its potential extends beyond the heating market when paired with power-to-heat solutions (heat pump, electrical heaters). By converting surplus electricity into heat, TES not only secures low-cost thermal energy but also enables participation in electricity markets. This flexibility creates multiple revenue streams and cost-saving opportunities. Its dual ability to source and deliver energy flexibly makes it an economically attractive and strategically important technology for industrial decarbonization.

Lower operating costs through electricity market participation

TES provides multiple pathways to optimize electricity use and reduce operational expenses:

- Power Purchase Agreements (PPA): TES allows more flexible utilization of PPAs, helping companies capture and optimize energy cost savings.
- Arbitrage: By storing electricity during periods of low or negative prices and converting it to electricity during peak demand, TES leverages market price differentials to minimize costs and generate additional revenue.
- Frequency regulation: Flexible power-to-heat systems can participate in ancillary service markets such as an automatic Frequency Restoration Reserve (aFRR), supporting grid stability while unlocking new income streams.
- Capacity payments: Reliable Long-Duration Energy Storages (LDES) with an integrated heat-to-power unit can benefit from government payments rewarding firm, secure capacity.

Peak Shaving

By dampening peak loads, the required peak power can be reduced, resulting in lowered grid connection costs and grid fees.

Cogeneration potential

TES can be combined with steam turbines or other heat-to-power systems to simultaneously generate heat and electricity. This dual operation enables participation in both thermal and electricity markets, enhancing energy efficiency and economic performance.

The decarbonization impact

TES has the potential to revolutionise industrial heat supply, significantly reducing global reliance on fossil fuels. Estimates suggest that electrically charged TES could replace up to 40% of current gas use in industry and avoid up to 14% of projected global energy-related greenhouse gas emissions by 2050 [1]. Increased solar thermal heating and waste heat recuperation enabled through TES integration extends this potential even further.

TES integration

Ensures Continuous & Reliable supply, improving process stability and uptime.

Improves Cost savings by utilizing low-cost electricity and recovered waste heat.

Leverages Revenue stacking by incorporating additional revenue streams.

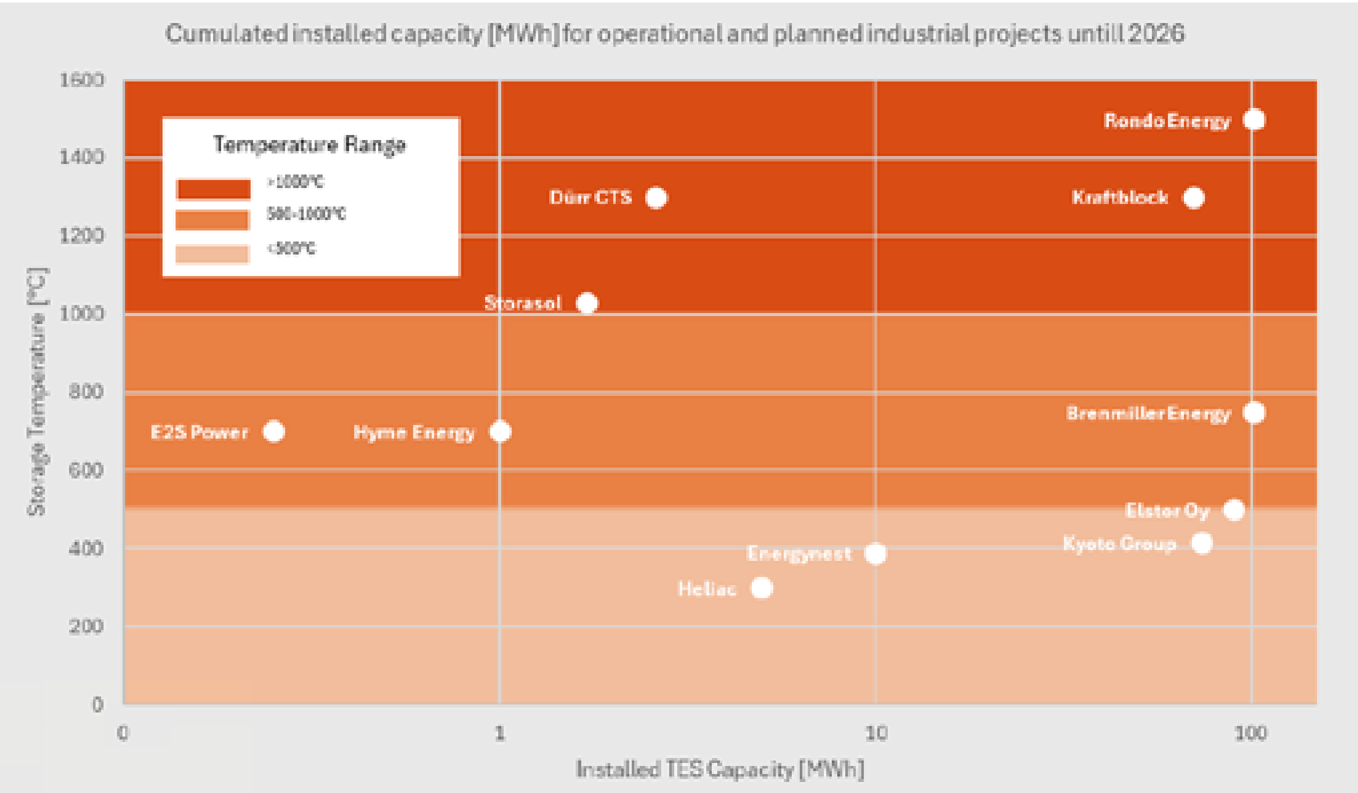
[1] SystemIQ (2024). Catalysing the global opportunity for electrothermal energy storage, Systemiq.

Section 2: Technology providers

Current status of the TES market

Thermal Energy Storage (TES) is a well – established technology in the Concentrated Solar Power (CSP) sector, with numerous reference plants demonstrating proven performance and reliability. Molten-salt storage – a common form of TES in CSP plants – currently has an installed capacity of **491 GWh** and is projected to grow to **650 GWh by 2030.** In parallel, other TES technologies are emerging as commercially viable solutions for storing surplus energy from CSP, solar photovoltaics (PV) and wind.

At the same time, new actors are entering the industrial thermal energy storage segments, bringing innovative TES solutions tailored to process heat, renewable integration and flexible energy management. These emerging applications aim to unlock additional value in industrial heat supply, electricity market participation and decarbonization efforts, creating a rapidly evolving market landscape.



Depending on how they store heat, TES solutions fall into three main categories:

- Sensible TES increases the temperature of a solid or liquid material insulated from the surroundings. For instance, thermal concrete can be heated to the desired temperature, store the heat and release it later for industrial processes.
- Latent TES leverages the phase change of materials –such as the melting of metals or the vaporization of liquids – to store and release thermal energy efficiently.
- Thermochemical TES relies on reversible chemical reactions that absorb heat during charging and release it during discharging. [1]

Except for a few companies such as Cartesian, most current commercial technologies are based on sensible heat storage. Latent and thermochemical heat storage systems are close to market entry, offering, among other benefits, higher storage densities and stable charging and discharging temperatures.

[1] WBCSD, Renewable industrial heat navigator brief: Thermal energy storage. 2025.

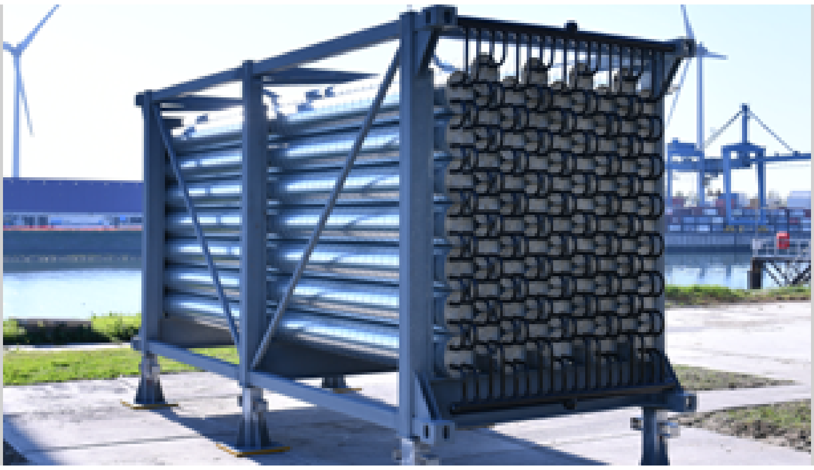
Key paramenter

Parameter	Value	Context
Energy source	power and heat	TES solutions can be charged directly by heat, generated for example by a concentrated solar thermal plant (heat-to-heat), or by electricity using resistive heating (power-to-heat).
TRL	7-9	As this Handbook focuses on operational solutions, the Technology Readiness Level (TRL) is high.
Spacial usage	0.5 to 4,5 m^2/MWh (TES only) 10 m^2/MWh (full system)	The footprint of TES solutions is up to 60 times smaller than that of Li-ion batteries due to their higher energy density and the ability to stack storage containers vertically.
Architecture	modular, scalable	Most systems are built with stacked storage containers, which gives the ability to easily scale systems.
Operating mode	Parallel charging and discharging	Most TES solutions can simultaneously be charged and discharged.
LCOH	80-235 €/kWh (full price) 60-100 €/kWh (only TES stack)	It depends on which components are included in the calculated levelised cost of heat (LCOH). The shown values have to be handled with care.
Energy input and output	steam, hot air, electricity	High flexibility in media; output is often tailored to industrial steam or process heat.
Dis-/Charging temperature	300 °C up to 1350 °C	Ranges from medium-temperature rock storage to high-temperature ceramic or sand.
Power in and out	up to 150 MW_{in} and 50 MW_{out}	Primary focus is thermal output, though some offer Power-to-Power.
Heat in and out	up to 100 MW	Thermal power ratings vary based on modular configuration.
Dis-/Charging efficiency	95% to 100%	High internal efficiency for heat transfer; electrical round-trip is lower (approx. 40%).
Storage material	molten salt, rock, graphite, or ceramics	Most systems that are on the market today are using sensible storage material. Phase change materials, e.g., are also increasing.
Storage temperature	up to 1300 °C	Higher temperatures correlate with high-density ceramic or graphite media.
Storage capacity	up to 1000 MWh	Highly scalable from single 20 ft container modules to large-scale tank farms.
Standstill losses	2% to 7% per day	The loss of stored energy per day is highly dependent on the size of the system.

Overview of TES providers

Provider	Location	TRL	Storage Temp. [°C]	Storage capacity	Storage media	Charge	Discharge	Use case
Low temp								
ENERGYNEST	Norway	9	390	2 MWh per module	Thermal concrete	Heat exchanger pipes	Heat exchanger pipes	#5; #12
Kyoto Group	Norway	8 - 9	200 - 450	56 MWh (demo)	Ternary salts	Electic heater	Steam	#2; #3
Heliac	Denmark	6	330	> 10 MWh	Packed rock bed	Electric heater	Steam	
Medium temp								
Elstor Oy	Finland	8	500	5 - 20 MWh	Structure of solid materials	Electricity	Steam	#4
Hyme Energy	Denmark	6	550	100 - 800	Molten salts	Heat	Steam	#14
Brenmiller Europe	Spain	8 - 9	750	> 30 MWh	Crushed rocks	Embedded heating elements	Embedded steam generator	#6; #11
E2S Power	Switzerland	7	700	> 5 MWh	Graphite	Internal heater	Rankine cycle	#13
High temp								
Storasol	Germany	9	1030	0,05 - 1000 MWh	Silica sand, basalt, iron silicate	Electrical heater, waste heat	Steam turbine, Gas turbine, Hot air, Steam, heat exchanger	#8
Dürr CTS	Germany	8	1300	5 - 50 MWh	Ceramic	Resistive heater	Rankine Cycle	#7
Kraftblock	Germany	8	1300	70 MWh per module	Ceramic pellets and bricks	External heat exchanger	Hot air	#10
Rondo Energy	USA	9	1500	300 MWh	Refractory bricks	Hot air	Hot air	#1 #9
Electrified Thermal Solutions	USA	6	1800	25 MWh	Joule Hive, bricks	E-Bricks	External steam generator	

ENERGYNEST



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Summary of technology

ENERGYNEST's ThermalBattery™ is a modular thermal energy storage system utilizing solid-state storage material HEATCRETE®, designed for high-temperature applications with high thermal capacity and conductivity. The system is flexible, allowing integration with various heat transfer fluids and charging mechanisms.

Key Features

- Modular TES with about 2 MWh per module, in a standard 20 feet container, which ensures fast installation and limited maintenance needs.
- Core technology is the solid material HEATCRETE®, developed for high-temperature usage with high thermal capacity and thermal conductivity.

Headquarters location: Norway
Contact person: Jonas Witt
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Email: jw@energy-nest.com
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Overall System

Energy source Power and Heat	**TRL** 9	**Spacial usage**
Architecture Modular, Scalable	**Operating mode** Parallel charging and discharging	**LCOH**

Charging	Thermal Energy Storage (TES)	Discharging
Type Heat exchanger pipes	**Technology** Sensible Solid	**Type** Heat exchanger pipes
Energy input Electricity, Thermal Oil	**Storage type** HEATCRETE (thermal concrete)	**Energy output** Thermal Oil
Charge temperature 390 °C	**Storage temperature** 390 °C	**Discharge temperature** < 300 °C
Power$_{in}$ [MW$_{el}$] > 1	**Storage capacity** 2 MWh per module	**Power$_{out}$ [MW$_{el}$]** 0
Heat$_{in}$ [MW$_{th}$] > 1		**Heat$_{out}$ [MW$_{th}$]** > 1
Charging Efficiency ~100%	**Standstill storage losses** ~2%/day	**Discharging Efficiency** ~100 %

Reference use cases

Enduser	Location	Application	Status	Case
YARA International	Norway	Power to Heat	Operational, 2023	# 5
Leonhard Kurz	Germany	Power to Heat	Groundbreaking, 2026	# 12

Kyoto Group

Summary of technology
Kyoto Group's Heatcube is utilizing molten salt as the storage medium and can deliver heat at temperatures up to 415 °C. The system is capable of both charging and discharging, allowing for flexible energy management. Charging can be achieved by heating the molten salt with electric heaters, through electricity from renewable sources or the grid. Discharging involves extracting the stored thermal energy to generate steam or hot air, which can then be used directly in industrial processes.

Key Features

- Modular and scalable thermal energy storage (TES) with tanks sizes > 13 MWh.
- Heatcube is designed for easy integration, connecting seamlessly to existing steam or hot air systems and offers a lifespan of over 25 years with minimal maintenance.

Headquarters location: Norway

Contact person: Nikolai Østråt Owe
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Website: www.kyotogroup.no

Overall System

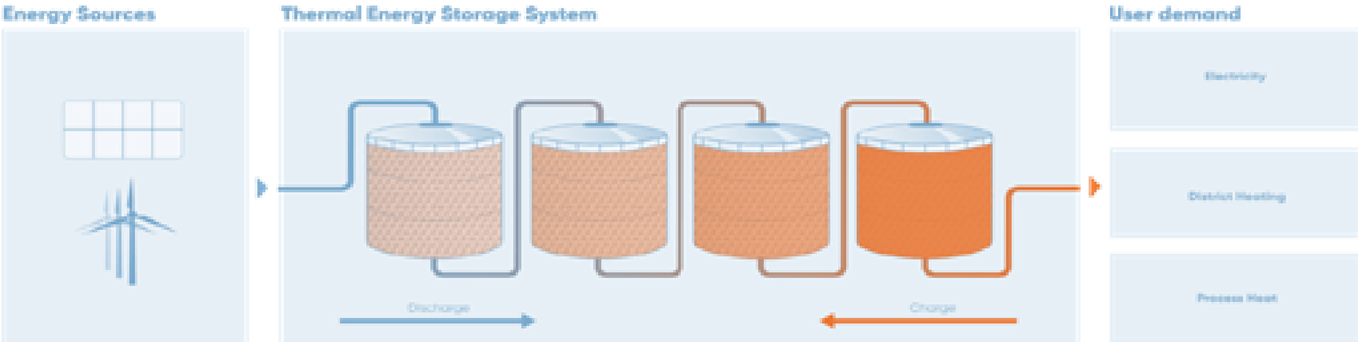
Energy source Power and Heat	**TRL** 8 - 9	**Spacial usage** TES: 1,43 m²/MWh
Power ramp-up/down	**Operating mode** Parallel charging and discharging	**LCOH**

Charging	Thermal Energy Storage (TES)	Discharging
Type Electric Heater	**Technology** Sensible Liquid	**Type** Internal steam generator
Energy input Electricity	**Storage type** Ternary salts	**Energy output** Steam
Charge temperature 450 °C	**Storage temperature** 220 - 450 °C	**Discharge temperature** 250 - 415 °C
$Power_{in}$ [MW_{el}] 5	**Storage capacity** 56 MWh (Demonstrated)	**$Power_{out}$ [MW_{el}]** 0
$Heat_{in}$ [MW_{th}] 0		**$Heat_{out}$ [MW_{th}]** 4
Charging efficiency 99%	**Standstill storage losses** 3 - 7%/day	**Discharging efficiency**

Reference use cases

Enduser	Location	Application	Status	Case
Aalborg Forsyning	Denmark	Power to Heat	Operational, 2023	#3
KALL Ingredients Kft	Hungary	Power to Heat	Operational, 2025	#2

Heliac



© Heliac

Summary of technology
Heliac's RockStore is a medium-temperature thermal battery storing surplus or renewable electricity as heat (up to ~300 °C) in solid rock media for industrial or district-heat applications.

Key Features
- Uses inexpensive solid rock/stone storage media (granite or similar) in a modular steel-vessel system, enabling cost-effective, long-duration heat storage
- Integrates with low-voltage electric heating (or excess renewables) for charging and delivers process heat or district heating without need of high-temperature molten salts.

Headquarters location: Denmark

Contact person: Dan Kofoed
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Website: www.heliac.dk

Overall System

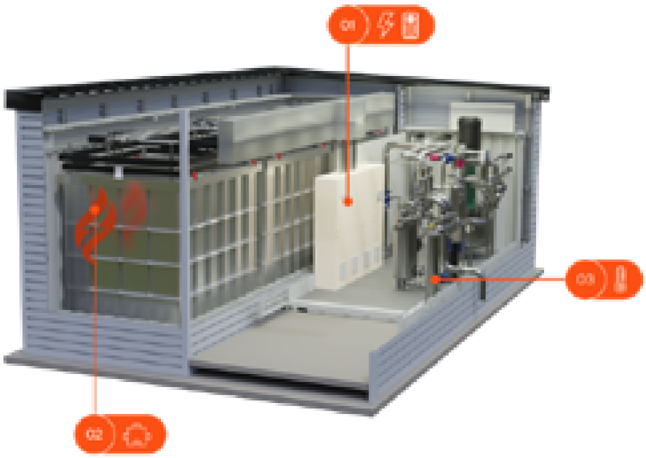
Energy source Power and Heat	**TRL** 6 (P2H -> 9)	**Spacial usage**
Architecture Modular, Scalable	**Operating mode**	**LCOH** ~ 60 €/MWh

Charging	Thermal Energy Storage (TES)	Discharging
Type Electric resistive heater	**Technology** Sensible solid	**Type** Steam generator
Energy input Electricity, Thermal Oil	**Storage type** Packed rock bed	**Energy output** Thermal oil, Steam, Hot water
Charge temperature 350 °C	**Storage temperature** 330 °C	**Discharge temperature** 330 °C
$Power_{in}$ [MW_{el}] 3 - 100	**Storage capacity** > 10 MWh	**$Power_{out}$ [MW_{el}]** 0
$Heat_{in}$ [MW_{th}] 3 - 100		**$Heat_{out}$ [MW_{th}]** < 1
Charging efficiency ~95%	**Standstill storage losses**	**Discharging efficiency**

Reference use cases

Enduser	Location	Application	Status	Case
Heliac Australia	Australia	Power to Heat	Construction, 2025	

Elstor Oy



© Elstor Oy

Summary of technology

Elstor's thermal energy storage (TES) system is a modular "power-to-heat" storage battery that uses electricity to charge thermal mass and discharges as steam or heat for industrial/district-heating applications.

Key Features

- Enables fossil-free steam and heat production by storing renewable or off-peak electricity as high-temperature thermal energy.
- Modular units (5 MWh per unit) allow industrial users to shift heat production into low-cost electricity windows and participate in grid demand-response.

Headquarters location: Finland

Contact person: Kari Suninen
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Website: www.elstor.fi

Overall System

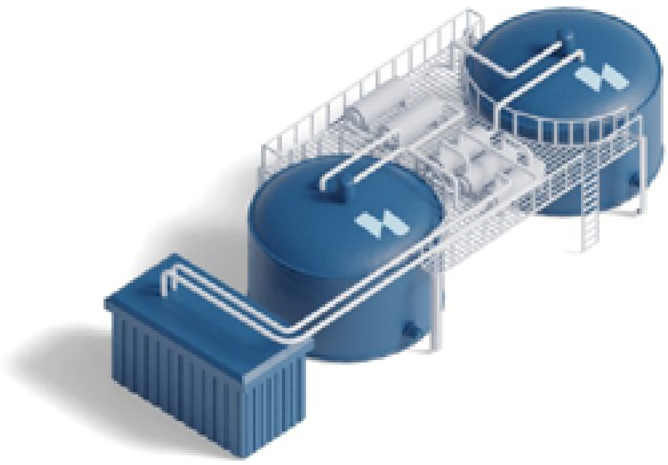
Energy source Power and Heat	**TRL** 8	**Spacial usage** 4,45 m²/MWh (storage only)
Power ramp-up/down Response time < 1.0 s (charge/discharge)	**Operating mode** Parallel charging and discharging	**LCOH** 30 - 100 €/MWh

Charging	Thermal Energy Storage (TES)	Discharging
Type Electrical resistance heating	**Technology** Sensible solid	**Type** Steam generator
Energy input Electricity	**Storage type** Structure of solid materials	**Energy output** Steam
Charge temperature 500 °C	**Storage temperature** 500 °C	**Discharge temperature** up to 250 °C
Power$_{in}$ [MW$_{el}$] 1,5 - 6	**Storage capacity** 5 MWh$_{th}$ per unit	**Power$_{out}$ [MW$_{el}$]** 0
Heat$_{in}$ [MW$_{th}$] 0		**Heat$_{out}$ [MW$_{th}$]** up to 4
Average total efficiency Reported efficiencies 95%	**Standstill storage losses** ~ 1,5%/d	**Discharging efficiency**

Reference use cases

Enduser	Location	Application	Status	Case
Herkkumaa Oy	Finland	Power to Heat	Operational, 2023	#4

Hyme Energy



© Hyme Energy

Summary of technology
Renewable electricity heats salt to 600 °C using resistance heaters. The salt is pumped from a colder tank to a hot tank while being heated. The hot salt, charged with energy, is stored in a tank until needed. To discharge, the hot salt is pumped through a steam generator, evaporating water to steam for industrial heat or cogeneration. The cooled salt cycles back to the cold tank for reuse.

Key Features
- Designed for steam-based industrial processes with a continuous steam demand of min 8 MW.
- The system ensures a flexible energy input and output by high energy density via system compactness.

Headquarters location: Denmark

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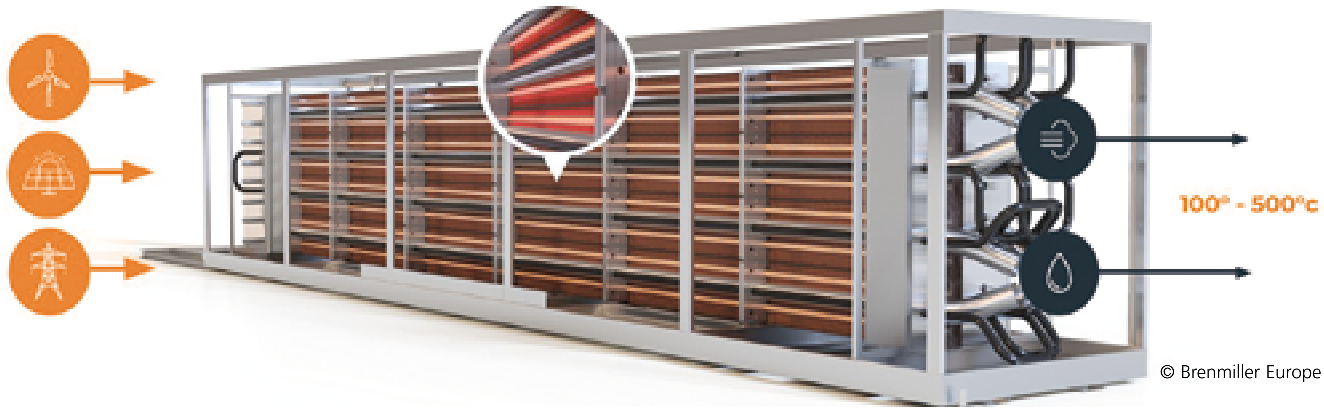
Overall System		
Energy source Power and Heat	**TRL** 8 (9 -> P2H)	**Spacial usage**
Power ramp-up/down	**Operating mode** Parallel charging and discharging	**LCOH**

Charging	Thermal Energy Storage (TES)	Discharging
Type Electrical resistance heating	**Technology** Sensible liquid	**Type** Embedded steam generator
Energy input Electricity	**Storage type** Molten salt	**Energy output** Steam
Charge temperature 550 °C	**Storage temperature** 550 °C	**Discharge temperature** 550 °C
$Power_{in}$ [MW_{el}] 18 - 150	**Storage capacity** 100 - 800 MWh_{th}	**$Power_{out}$ [MW_{el}]** 0
$Heat_{in}$ [MW_{th}] n/a		**$Heat_{out}$ [MW_{th}]** 10 – 50
Average total efficiency Reported efficiencies ~90%	**Standstill storage losses**	**Discharging efficiency**

Reference use cases

Enduser	Location	Application	Status	Case
MOSS	Denmark	Power to Heat	Commissioning, 2025	#14

Brenmiller Europe



Summary of technology
Brenmiller has developed a solution to decarbonize heat in industry, based on electrification and thermal storage. Integrating a steam generator and an electric heater, this system can be directly powered by renewable energy sources such as solar and wind energy, or by the grid and can produce heat on demand (up to 500 °C and 90 bar for steam). Its applications are varied, ranging from the use of surplus renewable energy production to optimizing electricity purchases on the SPOT market and providing services to the grid.

Headquarters location: Spain

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Website: bren-energy.com

Key Features
- Separation of charging and discharging, using dedicated heat transfer fluid (HTF) channels, enabling simultaneous charge and discharge operations when needed.
- High durability, with a lifespan exceeding 30 years and unlimited charge-discharge cycles.

Overall System

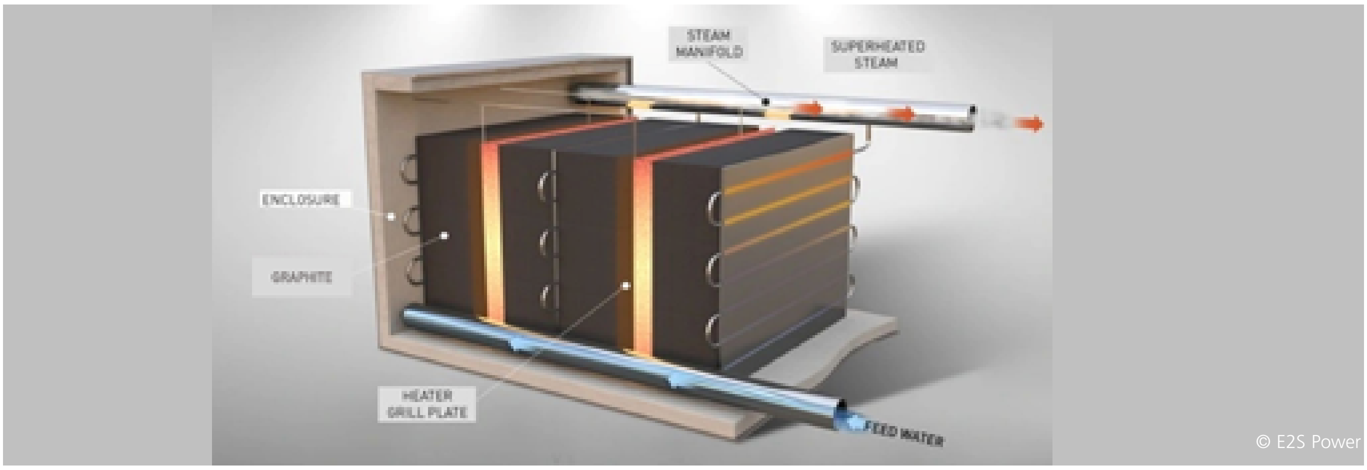
Energy source Power and Heat	**TRL** 8 - 9	**Spacial usage** 0.55 m^2/MWh (storage only)
Power ramp-up/down Discharge: 0,5 - 1%/s; Charge: 5%/s	**Operating mode** Parallel charging and discharging	**Capex** 60 - 80 €/kWh (Project dependent)

Charging	Thermal Energy Storage (TES)	Discharging
Type Embedded heating elements	**Technology** Sensible solid	**Type** Embedded steam generator
Energy input Electricity, Steam, Flue Gases	**Storage type** Crushed rocks	**Energy output** Hot air, Steam, Hot water, Thermal oil
Charge temperature Up to 750 °C	**Storage temperature** 750 °C	**Discharge temperature** 150 - 250 °C ideal, up to 500 °C
$Power_{in}$ [MW_{el}] 5 (scalable up to 100)	**Storage capacity** 30 MWh (scalable up to 1000 MWh)	**$Power_{out}$ [MW_{el}]** 0
$Heat_{in}$ [MW_{th}] 4,85		**$Heat_{out}$ [MW_{th}]** 1 – 2 (min; demonstrated)
Charging efficiency > 99%	**Standstill storage losses** < 2%/day	**Discharging efficiency**

Reference use cases

Enduser	Location	Application	Status	Case
Fortlev	Brazil	Heat to Heat	Operational, 2022	#6
Tempo Beverage Ltd	Israel	Power to Heat	Construction	#11

E2S Power



Summary of technology
TWEST is a compact “all in” standardized module that does not require any additional auxiliary equipment, external heat exchanger or additional working fluids.

Key Features

- High efficiency of charge and discharge process due to high thermal conductivity and direct conduction heat transfer between the storage media and the steam generator (no auxiliary losses for blowers or heat exchanger).
- Compact design: all in one container (storage, steam generation, electrical charging); small footprint and no moving parts: low requirements on maintenance.

Headquarters location: Switzerland

Contact person: Sasha Savic
Email: sasha.savic@ssa-power.com
Website: e2s-power.com

Overall System

Energy source Power and Heat	**TRL** 7	**Spacial usage** 6 m^2/MWh_{th}
Power ramp-up/down steam available in 5 minutes	**Operating mode** Parallel charging and discharging	**LCOH [€/MWh]** 40 (P2H); 150 (TES); 100 (H2P)

Charging	Thermal Energy Storage (TES)	Discharging
Type Internal Heater	**Technology** Sensible solid	**Type** Rankine Cycle
Energy input Electricity	**Storage type** Graphite	**Energy output** Steam, Electricity
Charge temperature 1000 °C	**Storage temperature** 700 °C	**Discharge temperature** up to 550 °C
$Power_{in}$ [MW_{el}] > 1	**Storage capacity** > 5 MWh	**$Power_{out}$ [MW_{el}]** > 10
$Heat_{in}$ [MW_{th}] 0		**$Heat_{out}$ [MW_{th}]** > 5
Charging efficiency 99%	**Standstill storage losses** 5%/day	**Discharging efficiency** 99% (steam) / 40% (power)

Reference use cases

Enduser	Location	Application	Status	Case
Pharmaserv Marburg	Germany	Power to Heat	Construction, 2026	#13

Storasol

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Summary of technology

The STORASOL HTTES-technology is capable of storing high temperature heat and delivering hot air during discharging or steam.
The STORASOL OPTES-battery is a Carnot Battery system based on STORASOL HTTES-technology. In the standard configuration, it operates either in a closed Brayton Cycle, or as OPTES-GT (open Brayton Cycle) for power generation. Alternatively, it can also use an organic Rankine cycle or steam Rankine cycle for power generation.

Key Features

- Standard electrical heater technology; for large capacities, parallel heaters. Proven air fans for moving the heat transfer medium.
- Innovative and patented arrangement of storage medium allows for very low pressure loss and therefore low electricity consumption during charging and discharging. Thin thermocline. Modular arrangement. Environmentally friendly (sand, insulation, steel).

Headquarters location: Germany

Contact person: Günter Schneider
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Email: guenter.schneider@storasol.com
Website: www.storasol.com

Overall System

Energy source Power and Heat	**TRL** 9	**Spacial usage** 6 - 10 m²/MWh_{th}
Architecture Modular, Scalable	**Operating mode** Parallel charging and discharging	**LCOH**

Charging	Thermal Energy Storage (TES)	Discharging
Type Electrical heater, waste heat	**Technology** Sensible solid	**Type** Steam/ gas turbine, heat exchanger
Energy input Electricity, hot gas (Air, N2, CO_2)	**Storage type** Silica sand, basalt, iron silicate	**Energy output** Air, N_2, CO_2 => Hot air, electricity, steam
Charge temperature 1030 °C	**Storage temperature** 1030 °C	**Discharge temperature** 1020 °C
$Power_{in}$ [MW_{el}] 0,015 - 100	**Storage capacity** 0,05 - 1000 MWh	**$Power_{out}$ [MW_{el}]** 0,01 - 50
$Heat_{in}$ [MW_{th}] 0,01 - 100		**$Heat_{out}$ [MW_{th}]** 0,03 - 1000
Charging efficiency 98%	**Standstill storage losses** 1 - 2%/day	**Discharging efficiency** 96%

Reference use cases

Enduser	Location	Application	Status	Case
Demonstrator	Germany	Heat to Power	Operational, 2015	#8

Dürr CTS

Summary of technology
Dürr's compact, modular heat-recovery and thermal-storage approach enables integration into existing plants with a minimal footprint, using stable media and avoiding critical heat transfer fluid or battery-type ageing.

Key Features

- Small footprint and modular skid-mounted deployment for easy retrofit into existing industrial plants.
- No usage of chemically-decomposing heat transfer fluids or battery type media, assuring stable capacity over the long term.

Headquarters location: Germany

Contact person: Philip Boergardts
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Email: Philip.Boergardts@cts-durr.com
Website: www.cts-durr.com/en

Overall System

Energy source Power and Heat	**TRL** 8	**Spacial usage** 1,58 m^2/MWh_{th}
Architecture Modular, Scalable	**Operating mode** Parallel charging and discharging	**LCOH**

Charging	Thermal Energy Storage (TES)	Discharging
Type Internal resistive heater	**Technology** Sensible solid	**Type** Organic Rankine Cycle
Energy input Electricity	**Storage type** Ceramic	**Energy output** Hot air => Electricity
Charge temperature 1350 °C	**Storage temperature** 1300 °C	**Discharge temperature** 1300 °C
$Power_{in}$ [MW_{el}] 0,5 - 4	**Storage capacity** 5 - 50 MWh	**$Power_{out}$ [MW_{el}]**
$Heat_{in}$ [MW_{th}] 0		**$Heat_{out}$ [MW_{th}]** 0,5 - 4
Charging efficiency 98%	**Standstill storage losses** 4 - 2%/day (depends on size of the unit)	**Discharging efficiency** 98%

Reference use cases

Enduser	Location	Application	Status	Case
FH Aachen	Germany	Power to Power	Operational, 2021	#7

Kraftblock

Summary of technology

Kraftblock stores thermal energy in a horizontal-flow packed bed. The HTF flows through the granulated material and releases or absors heat from it. The high maximum temperature and thermal properties of the TES material result in a high energy storage capacity.

Key Features

- The developed storage material is in the form of purposely produced pellets or bricks, with high heat capacity and thermal conductivity.
- The system provides a low capital cost by using cheap and recycled materials and a simple design.

Headquarters location: Germany

Contact person: Martin Schichtel
Email: martin@kraftblock.com
Website: www.kraftblock.com

Overall System

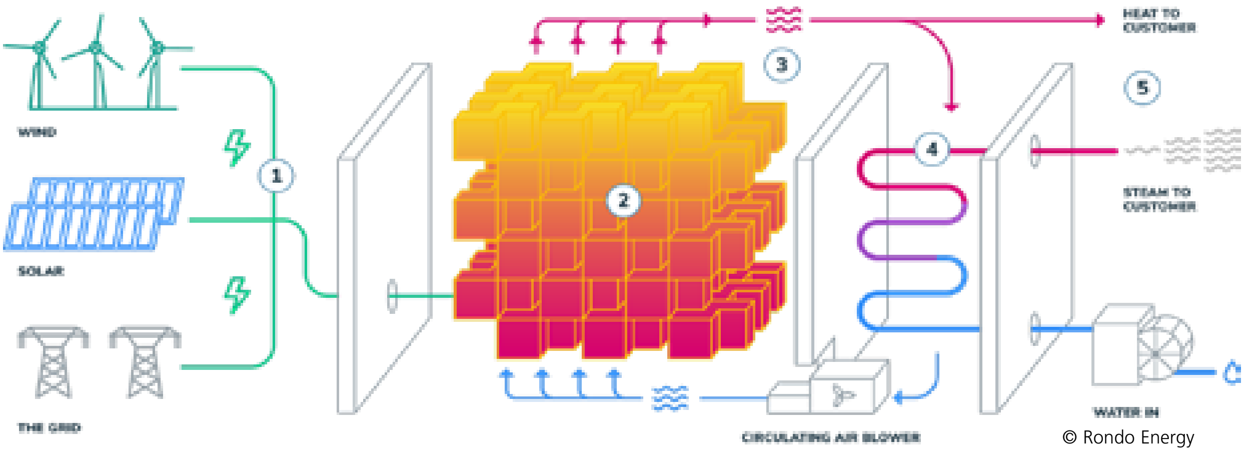
Energy source Heat	**TRL** 8	**Spacial usage** 1,2 MWh/m³
Architecture Modular, Scalable	**Operating mode** Parallel charging and discharging	**LCOH** 50 - 100 €/MWh

Charging	Thermal Energy Storage (TES)	Discharging
Type External heat exchanger	**Technology** Sensible solid	**Type** Heat
Energy input Hot air	**Storage type** Ceramic pellets and bricks	**Energy output** Hot air
Charge temperature Up to 1300 °C	**Storage temperature** 1300 °C	**Discharge temperature** up to 1200 °C
Power$_{in}$ [MW$_{el}$] 0	**Storage capacity** 70 MWh per module	**Power$_{out}$ [MW$_{el}$]**
Heat$_{in}$ [MW$_{th}$] 10		**Heat$_{out}$ [MW$_{th}$]** 10
Average efficiency 95%	**Standstill storage losses**	**Discharging efficiency**

Reference use cases

Enduser	Location	Application	Status	Case
PepsiCo	Netherlands	Power to Heat	Construction, 2025	#10

RONDO Energy



Summary of technology

The Rondo Heat Battery (RHB) is engineered to tackle heat at any industrial site, serving as a drop-in replacement for your fossil-fuel boiler. It captures the lowest-cost electricity, operates with the highest efficiency and safety and delivers the lowest-cost heat. The RHB provides seamless integration, ease of operability and has one of the tightest footprints in the industry. Configurable in size, units can be sized to rated outputs from 2MWth to over 100MWth.

Headquarters location: USA

Contact person: Jonathan Eckart
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Website: www.rondo.com

Key Features

- Rapidly captures low-cost, intermittent grid or renewable electricity (solar/wind) via adjustable resistive heating.
- Always-on, the heat battery delivers continuous (24/7) heat & power – as heat (steam, oil, air), or combined heat and power.

Overall System

Energy source Power	**TRL** 8-9	**Spacial usage**
Architecture Modular, Scalable	**Operating mode** Parallel charging and discharging	**LCOH**

Charging	Thermal Energy Storage (TES)	Discharging
Type Resistance heating	**Technology** Sensible solid	**Type** Heat
Energy input Electricity	**Storage type** Refractory bricks	**Energy output** Steam, oil, hot air
Charge temperature >1000 °C	**Storage temperature** >1000 °C	**Discharge temperature** up to 1000 °C
Power$_{in}$ [MW$_{el}$] 9 - 240+	**Storage capacity** 30 - 1000+ MWh	**Power$_{out}$ [MW$_{el}$]**
Heat$_{in}$ [MW$_{th}$]		**Heat$_{out}$ [MW$_{th}$]** 2 - 100+
Charging efficiency >97%	**Standstill storage losses** %/day (depends on size of the unit)	**Discharging efficiency** >97%

Reference use cases

Enduser	Location	Application	Status	Case
Holmes Western	USA	Power to Heat	Operational, 2025	#1
Covestro	Germany	Power to Heat	Groundbreaking, 2026	#9

Electrified Thermal Solutions

Summary of technology

An electrically-heated stack of conductive firebricks (the "Joule Hive™ Thermal Battery") converts intermittent clean electricity into ultra-high-temperature stored heat for dispatchable industrial use.

Key Features

- High-temperature operation enables compact, low-cost storage with high energy density and simplified plant layout.
- Electrified, high-voltage charging minimizes electrical balance-of-plant and improves round-trip plant efficiency.

Headquarters location: USA

Contact person: Phillip Stephenson
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Website: www.electrifiedthermal.com/

Overall System		
Energy source Power and Heat	**TRL** 6	**Spacial usage** 6,5 m²/MWh_{th}
Architecture Modular, Scalable	**Operating mode** Parallel charging and discharging	**LCOH** 60 - 100 €/MWh

Charging	Thermal Energy Storage (TES)	Discharging
Type Electricity heating element, E-Bricks	**Technology** Sensible solid	**Type** External steam generator
Energy input Electricity	**Storage type** Joule Hive, bricks	**Energy output** Hot air, Steam
Charge temperature 1800 °C	**Storage temperature** 1800 °C	**Discharge temperature** 1800 °C
$Power_{in}$ [MW_{el}] > 5	**Storage capacity** 25 MWh	**$Power_{out}$ [MW_{el}]** 100 - 530
$Heat_{in}$ [MW_{th}] 0		**$Heat_{out}$ [MW_{th}]** 5
Average total efficiency 95%	**Standstill storage losses**	**Discharging efficiency**

Section 3: Implemented & announced projects

Overview of reference projects

Use case	Capacity	Provider	End User	Location	COD*	Charging	Demand
Operational							
1	100 MWh	Rondo Energy	Holmes Western	USA	2025	Own electricity	Steam
2	56 MWh	Kyoto Group	KALL Ingredients Kft	Hungary	2025	Electricity from grid	Steam at 400 °C
3	18 MWh	Kyoto Group	Aalborg Forsyning	Denmark	2023	Electricity from grid	Steam => Hot water
4	10 MWh	Elstor Oy	Herkkumaa Oy	Finland	2023	Electricity from grid	Steam at 250 °C
5	4 MWh	ENERGYNEST	YARA International	Norway	2023	Steam grid	Steam at 189 °C
6	4 MWh	Brenmiller	Fortlev	Brazil	2021	Flue gas	Hot air at 350 °C
7	2,6 MWh	Dürr CTS	Solar Institute Jülich	Germany	2021	Electric heater	Electricity
8	1,5 MWh	Storasol	University of Bayreuth	Germany	2015	Gas burner	Electricity

* COD: Commercial Operation Date

Use case	Capacity	Provider	End User	Location	COD*	Charging	Demand
Under Construction							
9	100 MWh	Rondo Energy	Covestro AG	Germany	2026	Electricity from grid	Steam
10	70 MWh	Kraftblock	PepsiCo Inc.	Netherlands	2026	Electricity windfarm	Thermal oil at 300 °C
11	32 MWh	Brenmiller	Tempo Beverage Ltd.	Israel	2026	Electricity (grid and own)	Steam at 168 °C
12	12 MWh	ENERGYNEST	Leonhard Kurz	Germany	2026	Electricity	Thermal oil at 220 °C
13	6 MWh	E2S Power AG	Pharmaserv	Germany	2026	Electricity windfarm	Steam
14	1 MWh	Hyme Energy	MOSS	Denmark	2025	Electricity from grid	Water

Oil recovery system – charged with electricity from grid

Rondo Energy has begun the commercial operation of what it claims is the world's largest industrial heat battery: a 100 MWh system that is now in operation at a Holmes Western Oil facility in California. Supplied entirely by an onsite solar array, the system provides the plant with constant high-pressure steam and heat, demonstrating how renewable energy can directly power heavy industry. The new system runs alongside existing gas-fired boilers, delivering steam through the same infrastructure.

Using onsite solar power instead of natural gas helps Holmes Western Oil to hedge against energy price fluctuations and reduce its exposure to regulations and the carbon market. The Thermal Energy Storage started operation in September 2025.

End User: **Holmes Western**
Facility: Oil recovery system
Location: California, USA

© Rondo Energy

Charging	TES: E2S Power	Discharging
Own PV 20 MW	Sensible solid Refractory bricks Pilot Phase: 100 MWh	steam

Enablers

- Commitment from Holmes Western to hedge energy price fluctuations and reduce emissions
- Deployed in parallel with existing systems, doesn't require process redesign or new steam architecture.
- Integration possible without plant operation downtime
- Simplified permitting due to risk free materials

Barriers

First high temperature TES on a commercial scale carries increased investment risk.

End User Benefits

- **Cost Stability:** By replacing gas consumption with fixed-cost solar + storage, the system is designed to hedge against fuel price volatility and regulatory exposure.
- **Operational Efficiency:** Provides a continuous and reliable steam supply
- **Emissions reduction:** Eliminating reliance on fossil heat reduces Scope 1 emissions

Strategy

Hedging fuel prices by utilizing PV + storage for continuous steam supply

Business model

Financial

Capital Purchase by Holmes Western

Operational,
since 2025

Steam for food plant – charged with electricity from grid

Kyoto Group has deployed its molten-salt-based thermal energy storage system called Heatcube at the KALL Ingredients’ corn-processing facility in Hungary. The system stores energy (incl. possibly surplus renewables) as heat in molten salt tanks and delivers steam for industrial process heat under a heat-as-a-service model. It supports decarbonisation by replacing fossil-fuel boilers and enabling flexibility in the process-heat supply.

In November 2023, Kyoto, along with the financial partner Kyotherm and energy trading partner in Hungary, Energiabörze Kft, signed a commercial agreement for delivering Heat-as-a-Service (HaaS) to the Hungarian food ingredient producer KALL Ingredients Kft. The system was inaugurated on October, 2025 as the ”world’s largest industrial thermal energy storage unit” by Kyoto Group.

End User: **KALL Ingredients Kft**
Facility: Food ingredients plant
Location: Tiszapüspöki, Hungary

© Kyoto Group

Charging	TES: Kyoto Group	Discharging
Electricity from grid	Heatcube™ Molten salt 56 MWh	Steam 400 °C; 5 bar

Enablers

- Flexible operation in grid-balancing / reserve markets, enabling revenue streams
- Decoupling of electricity input (charging) and steam output (discharge), enabling use of intermittent renewables.
- Supports customer’s net-zero goals as a ”Scope 3 emissions reduction supplier,” enabling new business opportunities.

Barriers

Integrating a large molten-salt storage into an industrial steam system is technically complex and still novel in scale.

End User Benefits

- **Cost savings:** Replaces natural gas boilers with lower-cost renewable-charged heat
- **Grid balancing:** Enables participation in flexibility/ reserve markets while delivering heat
- **Emissions reduction:** Reduces around 8,000 tons CO_2 per year

Strategy: Steam-intensive manufacturing as a service.

Business model: Heat-as-a-Service (HaaS)

Financial: No specific public subsidy

District heating – charged with electricity from grid

Kyoto Group installed its first commercial “Heatcube™” molten-salt thermal energy storage system at Norbis Park (formerly Nordjyllandsværket) in Aalborg, Denmark. The unit uses electricity to heat molten salt to over 415 °C, stores the heat and then discharges it into the district-heating network, helping to phase out coal-based heat production and enabling participation in flexibility markets.

A commercial agreement was signed in November 2021 with Aalborg Forsyning for the Heatcube deployment at Norbis Park. The grid connection was commissioned in July 2023. The system passed its initial operational test in August 2023.

© Kyoto Group

End User: **Aalborg Forsyning**
Facility: District heating network operator
Location: Aalborg, Denmark

Charging	TES: Kyoto Group	Discharging
Electricity from grid	Heatcube™ Molten-salt 18 MWh	Steam => Hot water 4 MW

Enablers

- Modular molten-salt TES allowing decoupling of electricity input and heat output
- Integration into district heating system that is seeking to phase out coal – strong end-user commitment
- Ability to participate in grid flexibility/reserve markets (aFRR/mFRR) to minimize the price of electricity

Barriers

As a first commercial installation, long-term performance and maintenance profile still need full validation.

End User Benefits

- **Cost savings:** Reduces reliance on fossil-fuel-based heat production and associated fuel costs
- **Grid balancing:** Enables participation in flexibility/reserve markets while delivering heat
- **Emissions reduction:** Supports coal phase-out and lowers CO_2 emissions in district heating

Strategy: Replace the coal-fired heating of the district heating

Business model: Battery-leasing (BaaS) model

Financial: Commercial agreement between Kyoto Group and Aalborg Forsyning

Operational, since 2023

Steam for food processing – charged with electricity from grid

The system was developed under a contractual agreement signed in 2022 and became operational in May 2023. The TES unit integrates seamlessly with existing infrastructure, requires minimal downtime and operates with a daily charging/discharging cycle.

The contract between Herkkumaa and Elstor was announced around mid-2022. The 10 MWh unit was commissioned in May 2023. By September 2023, the system had already produced over 1000 MWh of steam, demonstrating early success.

End User: **Herkkumaa Oy**
Facility: Food-manufacturing
Location: Hämeenlinna, Finland

Charging

Electricity from grid, 100% certified carbon-neutral

TES: Elstor Oy

Sensible solid
10 MWh

Discharging

Steam
1,5 MW

Enablers

- Strong end-user commitment: Herkkumaa aiming for fossil-free steam production and replacing ~264,000 litres/year of light fuel oil
- Participation in grid flexibility markets: the TES system supports responsiveness to electricity price signals and grid services

Barriers

Integration into an existing production facility (site logistics, retrofitting around ongoing operations) is complex.

End User Benefits

- **Cost savings:** By replacing fossil-fuel boilers with electricity-charged heat storage, Herkkumaa stabilises production costs
- **Grid balancing:** Allows charging storage during low-cost or high-renewable electricity periods and supplying steam when needed
- **Emissions reduction:** The system enables elimination of ≈790 tonnes CO_2/year for the facility

Strategy

Replace the coal-fired heating of the district heating system

Business model

Heat-as-a-Service (HaaS)

Financial

Steam for chemical site – steam grid charged

YARA, a leading global chemical company, deployed a TES system from ENERGYNEST at its Porsgrunn plant in Norway to enhance steam generation efficiency and reduce fossil-fuel dependency. The TES is capable of a very short charge and discharge duration (5-6 cycles per hour) and is tailored to balance the steam demand at Yara's fertilizer production site. It uses the same piping specifications as the steam grid, which eases inspection and maintenance.

The project began in 2022, with EnergyNest and Yara collaborating to implement TES as part of Yara's decarbonization strategy. By utilizing waste heat recovery and grid electricity, the TES unit reduces natural gas consumption and enhances Yara's energy efficiency. This deployment aligns with Yara's long-term sustainability goals, ensuring a cost-effective and low-emission alternative to conventional fossil-fuel-based steam generation.

End User: **YARA International**
Facility: Ammonia and fertilizer production plant
Location: Porsgrunn, Norway

© ENERGYNEST

Charging

Steam grid
272 °C; 34 bar

TES: ENERGYNEST

ThermalBattery™
Sensible solid
(steel and HEATCRETE®)
4 MWh

Discharging

Steam
189 °C; 5 bar

Enablers

- Joint commitment from Yara and ENERGYNEST to reduce indirect CO_2 emissions by improving the efficiency of the steam grid
- Extra steam used for additional on-site electricity generation.
- Directly connecting to the steam grid

Barriers

A first-of-its-kind project carries increased engineering effort.

End User Benefits

- **Cost savings:** Optimizes energy efficiency by recovering and reusing heat, leading to significant fuel cost reductions
- **Grid balancing:** Smoother steam grid operation due to TES balancing; reduce dumping of excess steam
- **Operational efficiency:** Provides a continuous and reliable steam supply
- **Emissions reduction:** Reduce indirect CO_2 emissions

Strategy

Capturing and storing surplus heat for steam production reducing fossil fuel reliance

Business model

Financial

Availability of grants from Innovation Norway

Operational,
since 2021

Hot air for plastic manufacturing – charged from biomass flue gas

Brenmiller Europe supplied two 2-MWh bGen™ thermal energy storage units to Fortlev's plastic-tank manufacturing facility in Anápolis, Brazil. The system stores high-temperature heat in a crushed-rock heat battery and is charged using renewable biomass combustion at the site, enabling the plant to run moulding processes from stored heat rather than continuous fossil-fuel firing. The installation demonstrates industrial heat decarbonisation and on-site renewable integration.

For Brenmiller, it was the first commercial demonstrator. The project is now inspiring plans to expand deployment of Brenmiller's solution to another Fortlev manufacturing plant in Brazil.

End User: **Fortlev**
Facility: Plastic water-tank manufacturer
Location: Anápolis, Brazil

Charging

Biomass combustion,
flue gas (on-site)

TES: Brenmiller

Sensible solid (crushed-rock)
2 x 2 MWh; bGen™

Discharging

Hot air
400 °C

Enablers

- Availability of on-site renewable biomass fuel enabling low-carbon charging
- Industrial process compatibility (rotational moulding requires high-temp hot air) – good match for bGen discharge
- Modular, rock-bed TES technology that stores high-temperature heat for on-demand dispatch

Barriers

Site-specific integration complexity (fuel handling, flue management, process coupling)

End User Benefits

- **Cost savings:** Cuts fuel costs by 75% by substituting biomass for methane gas
- **Grid balancing:** Reduces dumping of biomass flue gas
- **Operational efficiency:** Provides a continuous and reliable steam supply
- **Emissions reduction:** Avoids 800 metric tons of greenhouse gas emissions annually

Strategy

Usage of on site biomass flue gas, reducing fossil-fuel reliance

Business model

Reduce fossil-fuel cost

Financial

Commercial deployment between Fortlev and Brenmiller

Operational,
since 2021

Hot air and electricity test facility

The pilot "multiTESS" facility at the Brainergy Park site in Jülich, Germany is a high-temperature thermal-energy storage (HTTES) research plant developed by SIJ and industrial partners including Dürr CTS, Kraftanlagen Energies & Services and Otto Junker. It uses ceramic-honeycomb storage modules storing air at up to ~1000 °C and incorporates an ORC (Organic Rankine Cycle) system and a Stirling engine to produce electricity from the stored heat.

End User: **Solar Institute Jülich**
Facility: MultiTESS Test Facility
Location: Jülich, Germany

Charging

Electric resistance heater

TES: Dürr CTS

Ceramics
2,6 MWh; 1000 °C

Discharging

Electricity, ORC Turbine

Enablers

- Scientific environment enables testing of integration into a variety of use cases
- Consortium of industrial and scientific partners offers a wide range of expertise
- Potential integration into district heating systems
- Potential provision of industrial process heat

Barriers

A first-of-its-kind project carries increased engineering effort.

End User Benefits

- **Grid balancing:** Flexible provision of electricity and heat at various temperatures
- **Cost savings:** Extensive experience in operation and application due to continuous research activity

Strategy

Usage of waste heat and surplus electricity for a flexible electricity and heat supply

Business model

Financial

Financing takes place via public funding and joint research projects with external partners

Operational, since 2015

Use case #8

Demonstration facility for high temperature TES with ORC

STORASOL's high-temperature thermal energy storage (HTTES) system was installed at the University of Bayreuth as part of the ORCTES Project (organic Rankine cycle + thermal energy storage) demonstrator. Two modular HTTES units store heat (sand/solid-bed) at up to ~600 °C and during discharge the heat drives an ORC turbine to generate electricity. The facility explores flexible charging/discharging of industrial-scale high-temperature storage.

The HTTES system is reported to be in operation since the end of 2015 at the University of Bayreuth.

End User: **University of Bayreuth**
Facility: University Test Facility
Location: Bayreuth, Germany

© Storasol GmbH

Charging	TES: Storasol	Discharging
Gas burner	Silica sand 1,5 MWh; 600 °C	Electricity, ORC turbine

Enablers

- Scientific environment enables testing of integration into a variety of use cases
- Usage of technologies established on the market (steam turbine, steam generator, etc.)

Barriers

A first-of-its-kind project carries increased engineering effort.

End User Benefits

- **Grid balancing:** allows decoupling of heat input timing from power generation (via ORC) and supports flexible dispatch
- **Operational efficiency:** Flexible heat and electricity supply

Strategy

Demonstrate and validate TES paired with ORC to enable power-to-heat-to-power cycles

Business model

Demonstration model

Financial

Financing of HTTES System was provided by Storasol, ORC-System and operation by University Bayreuth, funding from the State of Baden-Württemberg

Steam for chemical site – electrically charged

On January 19th, Covestro and Rondo celebrated the groundbreaking for the Rondo Heat Battery which is being built at Covestro's site in Brunsbüttel, Germany.
The Rondo Heat Battery charges when there is a surplus of low-price renewable energy in the grid, stores that energy in bricks, and delivers continuous high-temperature steam for on-site production processes. This offers a sustainable alternative to steam generation using fossil fuels, which are used in continuously running industrial processes, as the available amount of renewable energy at affordable prices fluctuates.

The 100 MWh Rondo Heat Battery (RHB) is scheduled to go into operation by the end of 2026. Breakthrough Energy Catalyst and the European Investment Bank (EIB) are supporting the project. The battery will produce ten percent of the required steam at the site, saving up to 13,000 tons of CO2 emissions per year.

End User: **Covestro**
Facility: ChemCoast Park
Location: Brunsbüttel, Germany

© Rondo Energy

Charging

Electricity from grid

TES: Rondo Energy

Rondo Heat Battery
refractory bricks
100 MWh

Discharging

Steam

Enablers

- Covestro as early customer for the electrothermal energy storage industry .
- Catalytic financing from European Investment Bank and Breakthrough Energy Catalyst.

Barriers

First of a kind TES project in Europe

End User Benefits

- **Cost savings:** replacement of fossil fuels and enables usage of low-price renewable energy
- **Emissions reduction:** saving up to 13,000 tons of CO2 emissions per year

Strategy

Decarbonized steam, decoupled from gas price

Business model

Financial

Catalytic financing from European Investment Bank and Breakthrough Energy Catalyst

Thermal oil for snack production – own REN charged

Kraftblock's Net-Zero Heat System is being installed at PepsiCo's snack-manufacturing facility in Broek op Langedijk, Netherlands. The system uses renewable electricity (via Eneco Groep N.V.) to convert power to high-temperature heat (~800 °C air), which is stored in modular containers of recycled material. The heat is then used to replace a gas-fired boiler for frying potato chips, significantly decarbonising the process.

The partnership was publicly announced in October 2022. Two storage modules (with ~70 MWh capacity) were planned for installation by end of 2023.

End User: **PepsiCo, Inc.**
Facility: Snack manufacturing plant
Location: Broek op Langedijk, Netherlands

© Credit: Eneco / Karin de Backer

Charging

Electrify from wind farm;
9 MW

TES: Kraftblock

Sensible solid
70 MWh; 800 °C

Discharging

Thermal oil
300 °C; up to 9 MW

Enablers

- Modular TES with capability of extended storage capacity, if needed (150 MWh planned)
- Simpler connection to the grid, as flexible capacity (using the connection only if demand is low)
- Availability of low-cost/renewable electricity via Eneco allows charging during off-peak or surplus period

Barriers

Integration into an existing production facility (site logistics, retrofitting around ongoing operations) is complex.

End User Benefits

- **Cost savings:** Replacement of fossil-fuel boilers with flexible use of stored renewable heat
- **Grid balancing:** Eneco can also provide ancillary services to the grid
- **Emissions reduction:** first step ~51% CO_2 reduction (~8,500 t CO_2/year) with aim for ~98%

Strategy: Scalable and adjustable TES module applied to end user needs

Business model: Heat-as-a-Service (HaaS)

Financial: Raised €20 million in a Series B financing

Beverage production – electrically charged

Brenmiller is deploying a 32 MWh bGen™ ZERO high-temperature thermal energy storage system at the Tempo Beverages' manufacturing facility in Netanya, Israel. The system will replace heavy fuel oil boilers and enable power-to-heat conversion, using crushed-rock storage to decouple electricity charging from industrial steam discharge.

Key construction milestones began in April 2025 with the civil base structure and insulation. Installation of the first "bCubes™" modules was planned for late May 2025, followed by completion of construction by September 2025.

End User: **Tempo Beverages Ltd.**
Facility: Beverage production plant
Location: Netanya, Israel

© Brenmiller Europe Ltd.

Charging

Electricity
(grid and rooftop solar)
5,6 MW_{el}

TES: Brenmiller

Sensible solid (crushed-rock)

32 MWh; bGen™

Discharging

Steam,
168 °C; 7 bar, 2,2 MW_{th}

Enablers

- Modular high-temperature TES (bGen™ ZERO) enabling decoupling of electricity charge/discharge cycles
- Replacement of heavy-fuel boilers with low-carbon electric heat, offering cost and emission advantages
- Fixed-rate steam supply contract structure (Energy-as-a-Service) reducing end-user capital risk

Barriers

Project still in construction/commissioning phase; full performance yet to be proven at scale

End User Benefits

- **Cost savings:** Project is expected to save Tempo approximately US$7.5 million over 15 years
- **Grid balancing:** Enables flexible heat generation aligned with off-peak or own renewable electricity.
- **Operational efficiency:** Provides reliable industrial steam from stored heat rather than continuous boiler firing
- **Emissions reduction:** Eliminates ~2,000 tons heavy fuel annually and reduces ~6,200 tons CO_2 per year

Strategy

Power-to-heat storage solutions that enable on-demand heat

Business model

Heat-as-a-Service (HaaS)

Financial

Israeli Ministry of Economy and Industry: approx. US$595 thousand

Steam for chemical site – electrically charged

ENERGYNEST is implementing a power-to-heat system with a ThermalBattery™ at LEONHARD KURZ's Sulzbach-Rosenberg production facility in Germany. The 3 MW_{el} electric heater and 12 MWh TES unit will charge with renewable or off-peak electricity and discharge heat into the existing thermal-oil system, replacing gas-fired boilers. The system is designed to produce over 3 GWh of clean process heat annually, covering more than 70% of one production-line's demand.

A commercial agreement between LEONHARD KURZ and ENERGYNEST was signed on March, 2025. On July, 2025 the groundbreaking ceremony was held. Commissioning is expected in mid-2026

End User: **LEONHARD KURZ**
Facility: Thin-film technology
Location: Sulzbach-Rosenberg, Germany

Charging

Electric heater,
3 MW_{el}, 390 °C,
grid + local PV

TES: ENERGYNEST

ThermalBattery™
Sensible solid
(steel and HEATCRETE®)
12 MWh

Discharging

Thermal oil,
3 GWh/year; 220 °C

Enablers

- Utilize excess solar energy from on-site PV field
- Modular, scalable ThermalBattery™ technology integrates with existing thermal-oil infrastructure
- Strong end-user commitment: KURZ's goal of CO_2-neutral production and its high-temperature process-heat demand

Barriers

Integration of new power-to-heat system into legacy plant infrastructure.

End User Benefits

- **Cost savings:** Reduces natural-gas boiler fuel costs via renewable-charged heat
- **Grid balancing:** Shifts electricity charging to times of surplus/off-peak supply
- **Operational efficiency:** Provides a continuous and reliable steam supply
- **Emissions reduction:** Cuts more than 700 tons of CO_2 per year.

Strategy: Capturing and storing energy from on-site PV

Business model: Heat delivery under long-term arrangement

Financial: Germany's Federal Ministry for Economic Affairs and Climate Action (BMWK)

Steam for pharmaceutical products – charged with own electricity

Pharmaserv, the industrial park operator of the Behringwerke site in Marburg, Germany, is deploying E2S Power's TWEST thermal energy storage system to gradually replace its gas-fired boilers and enable CO_2-neutral steam production. The storage system uses modular graphite blocks to convert electricity to heat and then generate steam for industrial processes. Phase 1 covers roughly 10% of steam demand, with Phase 2 envisaged to cover 100%.

Contract announcement in December 2024 for a 6 MWh pilot TWEST system. Inauguration and commissioning are scheduled for 2026. Phase 2 expansion to 60 MWh will be planned after initial pilot success.

End User: **Pharmaserv GmbH (Behringwerke industrial park)**
Facility: Pharmaceutical/industrial production
Location: Marburg, Germany

Charging

Electricity windfarm
Up to 700 °C

TES: E2S Power

Sensible solid;
Graphite; TWEST™
Pilot Phase: 6 MWh
2nd Phase: 60 MWh

Discharging

Pilot: supply 10%
of steam demand
2nd Phase: 13 MW

Enablers

- Modular, compact TWEST design that integrates with existing steam boiler/plant infrastructure and replaces fossil-fuel boilers
- High charge/discharge flexibility: storage can be charged during low-cost/renewable electricity periods and discharge continuously (24/7) for steam production

Barriers

Project currently at pilot scale (~6 MWh) so scaling to full steam-demand coverage (~100%) entails technical, financial and operational risk.

End User Benefits

- **Cost savings:** Reduces reliance on gas-fired boilers and exploits cheaper electricity for steam production
- **Grid balancing:** Enables shifting of electricity consumption (charging) to times with surplus/low-cost renewable power and providing steam when needed
- **Emissions reduction:** Strong decarbonisation commitment by the end-user (Pharmaserv's goal of carbon neutrality by 2030) supporting technology adoption

Strategy

Electrify industrial steam generation

Business model

CO_2 free operation and lower steam cost

Financial

Part of Pharmaserv's sustainability roadmap (neutral by 2030)

Steam for industrial demonstrator – charged with electricity from grid

Hyme Energy's MOSS (MOlten Salts Storage) project is the world's first demonstrator facility to store renewable electricity as high-temperature heat in molten hydroxide salts and produce steam for industrial uses. Located at Semco Maritime's facility in Esbjerg and supported by a consortium of industry & academia, it is designed to prove scalability and cost-effectiveness of long-duration thermal energy storage for high-temperature industrial heat.

The MOSS project was initiated in 2022. A steel-cutting ceremony marking installation start took place on September, 2023.

End User: **Semco Maritime**
Facility: MOSS molten-salt demonstrator energy-storage plant
Location: Esbjerg, Denmark

© Hyme Energy

Charging

Electricity from grid
1,3 MW
Up to ~600 °C

TES: Hyme Energy

Molten salt
500 °C; 1 MWh

Discharging

Steam,
1,2 MW

Enablers

- Demonstrator scale built by strong consortium (Hyme, Semco Maritime, Alfa Laval, Sulzer, Aalborg University) supporting technology maturation
- Novel molten hydroxide salt medium allows very high temperature storage (up to ~700 °C) enabling industrial-grade heat applications.

Barriers

As a demonstration project, scaling to commercial scale remains future work

End User Benefits

- **Cost savings:** Potentially lowering fuel-based steam generation costs by using stored renewable electricity
- **Grid balancing:** Shifts electricity charging to times of surplus/off-peak supply
- **Emissions reduction:** Supports decarbonisation of process heat by replacing fossil-fuel combustion with stored renewable-based steam

Strategy

Demonstrate and validate a scalable, molten salt storage technology to electrify industrial heat

Business model

Pilot model

Financial

Demonstrator has support of the Danish EUDP programme (grant of DKK 13.2 million of total budget of DKK 24.7 million)

Directory of TES providers

Please note that this manual does not provide an exhaustive list of all companies in the Thermal Energy Storage (TES) sector. While the market is rapidly expanding with a vast number of emerging startups, this selection focuses on established providers meeting specific criteria.

Providers may not be listed in this current version for several reasons:

- Industrial Maturity: A primary focus was placed on companies that have already successfully implemented industrial-scale projects or have confirmed such projects in the immediate pipeline. Purely research-oriented ventures were generally excluded
- Communication Status: In some cases, we were unable to establish direct contact or did not receive a response from the provider during the data collection period.

This handbook is a living document. We recognize the dynamic nature of the TES market and are committed to updating this directory as new information becomes available and new milestones are reached.

Provider	Location	Type
1414 Degrees	Australia	latent
247Solar Inc	USA	solid
Alumina Energy	USA	solid
Antora Energy	USA	solid
Brenmiller Europe	Israel	solid
Build to Zero	Spain	liquid (future PCM)
Calectra	UK	solid
Carbon-Clean Technology	Germany	solid
Cartesian	Norway	latent
Dürr CTS	Germany	solid
E2S Power	Switzerland	solid
Echogen	USA	solid
Eco-Tech Ceram	France	solid
Electrified Thermal Solutions	USA	solid
Element16	USA	liquid
Elstor Oy	Finland	solid
EnergyDome	Italy	solid
ENERGYNEST	Germany	solid
Enerin-As	Norway	solid
Epyr	France	solit
Exergy3	UK	solid
Fourth Power	UK	solid
Green-Y	Switzerland	solid/liquid (Hybrid)

Get in Touch

Is your company missing? If you represent a provider that has been omitted or have recently launched a new industrial project, we want to hear from you. We are committed to keeping this a living document that reflects the true state of the industry.

Join the Network & Collaborate
Let's build the future together. Beyond documentation, we are actively looking for research partners. If you are interested in exploring joint projects, or technical collaborations, please reach out directly. Let's turn thermal storage potential into industrial reality.

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Provider	Location	Type
Heatrix	Germany	solid
Heliac	Denmark	solid
HighView power	UK	solid
Hyme Energy	Denmark	liquid
Kaaj Energy	Canada	solid
Kraftanlagen	Germany	solid
Kraftblock	Germany	solid
Kyoto Group	Norway	liquid
Lumenion	Germany	solid
Magaldi GreenEnerg	Italy	solid
Malta Group	USA	liquid
MGA Thermal	Australia	latent
Pintail Power	USA	liquid
Polar Night Energy	Finland	solid
Push-CC	Spain	liquid
RayGen	Australia	solid
Redoxblox	USA	Thermochemical
Rondo Energy	USA	solid
Rpow	Spain	liquid
SaltX	Sweden	Thermochemical
Storasol	Germany	solid
Storworks Power	USA	solid
Sunamp	UK	Latent (PCM)
Terrajoule Energy	USA	liquid
Thermophoton	Spain	Latent (TPV)
TORC	UK	solid

DLR at a glance

The German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt; DLR) is Germany's national research and technology centre for aeronautics, space, energy, transport, security and defence. DLR's work spans a wide range of applications, delivering results and innovations that benefit industry and business, government agencies and the public sector. At the heart of DLR's mission is its commitment to society, which it fulfils through extensive knowledge sharing and targeted technology transfer. Therefor it is funded through federal resources. The German Space Agency at DLR is responsible for planning and implementing German space activities on behalf of the federal government. Additionally, two project management agencies at DLR manage research and industrial funding programmes.

Earth's climate is changing, along with global mobility and technology. DLR harnesses the expertise of its 51 research institutes and facilities to develop solutions to these challenges. All 11,000 employees share a common mission: to explore Earth and space while developing technologies for a sustainable future. DLR's technologies are not confined to the laboratory, but are transferred to wider society, strengthening Germany's position as a prime location for research and industrial innovation.

About Department Thermal Process Technology

The Department of Thermal Process Technology is an integral part of the Institute of Engineering Thermodynamics. It develops advanced thermal storage systems that drive the decarbonization of heat supplies and enhance the resilience of the electricity grid. Through the integration of Power-to-Heat and Power-to-Heat-to-Power solutions, the department enables a demand-oriented energy supply from renewable sources, ensuring grid stability across Central Europe.

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