DaCES
Danish Center for Energy Storage

# THERMAL ENERGY STORAGE

## ELECTRIFICATION WITH FLEXIBILITY

## 2025

**DANISH CENTER FOR ENERGY STORAGE (DaCES)**
Denmark must become a pioneering leader in research, development, application and integration of energy storage technologies that are competitive to a global market thereby contributing to reducing the climate footprint of the planet.

DaCES is a neutral and independent forum, working to guide research, education and innovation in energy storage and conversion. We are a member driven, network based and action-oriented organisation that brings together actors from research, industry and business in a professional manner.

We work across energy storage technologies and professional disciplines such as natural and engineering sciences, mathematics, social sciences, economics and humanities, etc. The goal is to create collaborations, networks and partnerships that bring together research environments and companies to address major societal challenges and reduce our dependency on fossil fuels.

**DaCES' working groups**
DaCES leads and facilitates four technical working groups in thermal storage, batteries, PtX and system integration, as well as a working group on education. We are also involved in a number of specialized subgroups related to energy storage and conversion.

For membership: www.daces.dk

DaCES is supported by the Novo Nordisk Foundation.

**Disclaimer**
DaCES has the sole responsibility for this report, which does not necessarily reflect the individual member organisations' own positions, but is based on the inputs from and discussion within DaCES working group for thermal energy storage.

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# FOREWORD

Our future climate neutral energy system will be primarily based on renewable energy production and its use in electrified processes throughout the system. This is good for the climate, but it exposes us to mismatches between energy production and consumption. This creates an immense need for developing energy storage and flexible energy consumption – so we can store excess energy and simultaneously reduce how much energy we need to store. Here, thermal energy storage (TES), and especially the high temperature variants (HT-TES) could play a much larger role in supporting a competitive electrification of our industries in Denmark and in Europe – by combining electrification, storage and flexible consumption.

The Danish Center for Energy Storage has prepared this report "Thermal Energy Storage, Electrification with Flexibility 2025". We believe that thermal energy storage (TES) is a largely overlooked set of technologies in establishing a robust, flexible and cost-effective energy system. TES is the most efficient and cheapest energy storage technology – when all you need is heat. Heat constitutes half of our final energy demand and roughly half of our greenhouse gas (GHG) emissions globally. In the report we will look into the potential of low temperature (0-100 ºC), cold and high temperature TES technologies and their role in developing flexible electrification.

The DaCES working group for thermal energy storage has discussed and contributed to this report. The working group gathers researchers and experts from universities, industry and Research Technical Organisations (RTOs) with activities in Denmark. With this report we want to stress that Denmark is one of the early innovators and adopters for both low and high temperature solutions where both universities, knowledge institutions and Danish companies are deeply engaged in national and international research, development and innovation projects.

Our report introduces some of the drivers and necessary focus areas for accelerating the development and uptake of TES in the large transition of our energy system. We wish to increase understanding and awareness of the large potentials in thermal energy storage among decision-makers, institutions and other central actors in the broad energy sector.

We hope to inspire for further dialogue on TES in our joint efforts to ensure a stable, sustainable energy system to the benefit of Denmark, our industry, R & D, growth, business and society.

Enjoy your reading.

**Anne Marie Damgaard**
Director,
The Danish Center for Energy Storage (DaCES)



**DaCES: THERMAL ENERGY STORAGE REPORT 2025**
DaCES' working group for thermal energy storage has prepared this report with Aksel Nordvig Ladegaard, technical consultant at DaCES, as project leader and Geoffroy Gauthier, PlanEnergi, chair of the thermal energy storage group.

Aksel Nordvig Ladegaard,
Technical consultant,
Danish Center for Energy Storage

Geoffroy Gauthier,
Chair of the thermal energy storage group, PlanEnergi

# INTRODUCTION TO THERMAL ENERGY STORAGE

Our society and quality of life have been enabled by a complex energy system, which is only possible due to the flexibility embedded in fossil fuels. Our future energy system based on intermittent renewables will require massive new sources of flexibility. This flexibility will be achieved through a combination of energy storage, conversion technologies, and smarter control of both energy generation and consumption. Especially, the need for economical and large storage capacities is where thermal energy storage truly excels. *For when the energy need is in the form of heat, the cheapest and most efficient energy storage technology is thermal energy storage; and since about half of the final energy consumption of modern societies is heating and cooling, TES stands out as a crucial player in the future energy system.*

This report will highlight some of the underutilized potentials of TES technologies – and recommends focus areas to realize them. The report will mainly deal with the emerging applications, as they enable TES to play a role in:
1. Protecting 20+ million quality jobs in the European union[1], 2. Increase overall energy system effectiveness and
3. Help decarbonize more than 25% of the world's $CO_2$-eq emissions[2] [5], [7], [8], [9].

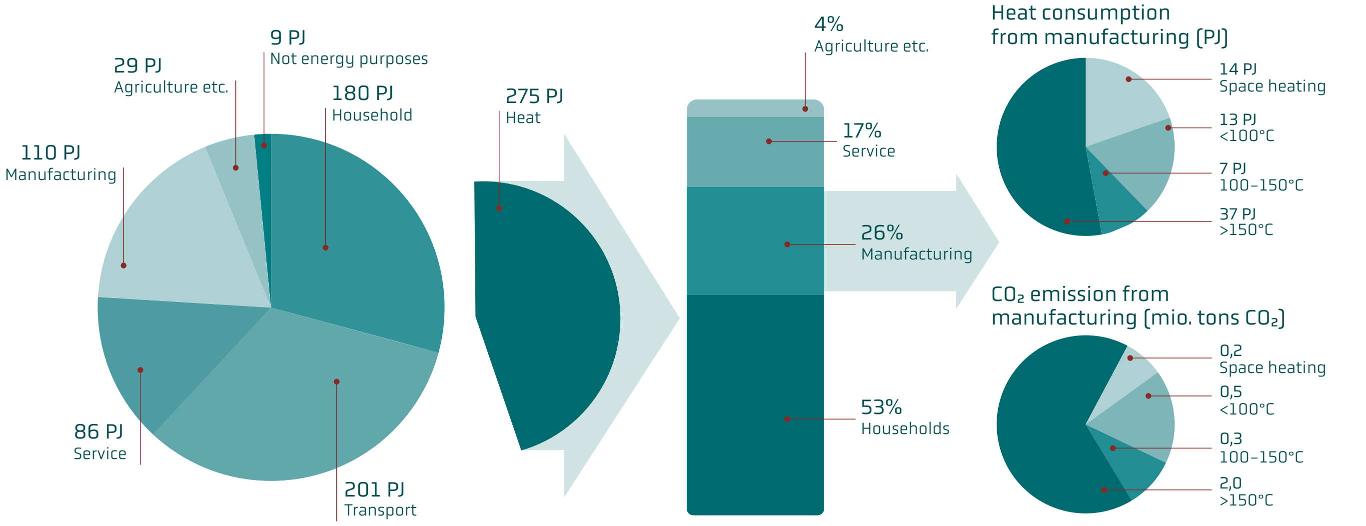



Figure 1: The final energy demand in Denmark in 2023. The same split between residential, industrial and transport generally holds worldwide, with some regional differences [10].

As illustrated in figure 1 one third of the final heat demand is for industrial processes, and most of this can be directly electrified with existing or maturing technologies. However, electrifying the industrial processes with TES will enable a more efficient, cheaper and ultimately more sustainable energy system [11], [12], [13]. This will happen through a larger flexibility in when the electricity is generated and used – enabling a better utilization of intermittent renewables, whilst minimizing energy costs for industry.

[1] Extrapolation of electrifiable industrial processes in EU and the amount of jobs directly created by those sectors, using data from European Commission Single Market and Agora Industry [5], [6].

[2] Lower estimate, also reductions in other pollutants.

For low temperature applications, especially in district heating and cooling, TES is a well-established and a commercial technology. However, adoption is still lacking, and there is a need for large scale adoption – and in many cases, ideally in conjunction with implementation of district heating/cooling.

The uptake of especially high temperature TES is, however, too slow to reach EU climate targets of 90% net emissions reductions in 2040 and climate neutrality by 2050. There is a rough estimate of 40.000 industrial boilers in the EU, mainly using gas, most of which should be electrified before 2050, to meet the EU climate goals [14], [15]. This is a pace of 1600 boilers per year assuming a deadline of 2050, which is much larger than existing delivery capacities, as technology providers can currently only deliver a few units per year. However, capacities could be scaled up very fast with the proper focus, as there is no significant technical limiting factor. Most TES solutions build upon well-established technologies and supply chains, enabling them to scale fast under the right framework conditions.

This report highlights five focus areas required to accelerate the pace of development and implementation of TES.

1. Limited awareness of the existing scale and opportunities in thermal energy storage.
2. Structural issues for financing high temperature thermal energy storage to sufficient scale.
3. Limited number of test facilities and capacity is bottlenecking development of high temperature thermal energy storage.
4. Missing long-term support for demonstrators is slowing uptake by large commercial players.
5. Lack of clear plans for the phase out of gas for process heat is delaying electrification efforts and uptake of TES by industry.

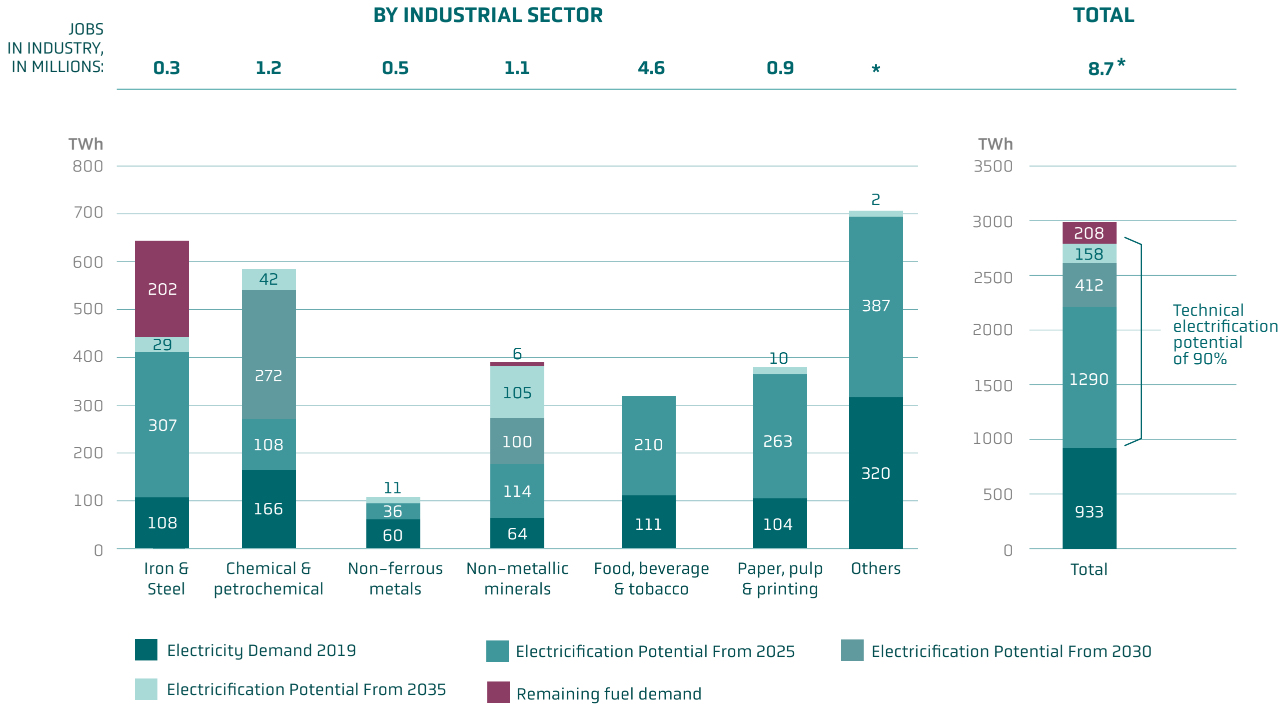



Figure 2: The large technical potential for direct electrification, with or without storage in the EU-27. Recreated from Agora Industry [5], with addition of jobs directly created by each industry, using European Commissions single market data [6].].



# LARGE POTENTIAL FOR USING THERMAL ENERGY STORAGE

There is an immense need for competitive decarbonization of industry, energy storage and energy efficiency - without creating social, economic or resource burdens, that will undermine the green energy transition. In this context, TES offers a wide set of technologies that enable:

1. Cost competitive electrification of industrial heat.
2. A higher value, flexibility and build out of renewables.
3. Energy efficiency improvements at all levels, from components to energy system level.
4. Reducing the need for scarce minerals whilst building upon European industrial strengths.

### 1. Need to decarbonize industrial process heat, in a sustainable and economical manner

Industrial process heat accounts for up to 3/4rds of emissions from industry, creating a pressing need to develop and scale solutions [5]. The solutions need to be economical sound, as recently stressed by the Mario Draghi report on the need to rapidly build Europe's industrial skills, sustainable technologies and competitiveness. [16]. Here, TES is an enabler for utilizing cheap intermittent renewable energy, as it enables much larger and cheaper storage capacities than its counterparts. And it is clear that large storage capacities are necessary for any cost-effective climate-neutral energy system [12], [13].

Other solutions, such as large reliance on hydrogen for process heat, are less energy efficient and require hydrogen infrastructure, incurring larger costs. The use of hydrogen should largely be limited to uses where there are no other options or where it provides unique capabilities, for example in long-duration energy storage and in the production of green fuels and chemicals.

### 2. Increasing need for flexibility in the energy system

Curtailment[1] of renewable energy resources reaches 2-8% in most markets with large shares of renewables and as more and more solar and wind is added to the grid [17]. Approximately 7% of wind production was curtailed in Denmark in 2021, roughly the annual electricity consumption of 750,000 Danes. Longer imbalances are also important to address, especially in the northern part of Europe , where there is an excess electricity generation in the summer and peak demand in the winter. This creates an opportunity for low-cost storage technologies, such as pit thermal energy storages (PTES) and similar, that can enable inter-week energy storage.

TES, particularly large, low-temperature systems such as PTES, has been shown in studies to play two distinct roles in the energy transition. Initially, TES enhances the efficiency of combined heat and power (CHP) plants by storing excess heat generated during peak electricity production, rather than wasting it. As the energy transition progresses, TES shifts its role to capturing surplus renewable electricity—such as from wind and solar—that would otherwise be curtailed [12], [13].

With fewer large controllable generators in the mix, the Danish TSO, Energinet is also stressing that power inadequacy is a real challenge in the coming decade for Denmark [18], [19]. Partial solutions include increasing offtake flexibility -the ability to shift energy consumption in response to supply conditions—and extending the duration for which large amounts of energy can be stored at a reasonable price.

### 3. Enabling energy efficiency improvements

Thermal energy storage can also contribute to energy efficiency improvements at the product-, process- and energy system level. However, the technologies, integrations and research, differ for each level.

At the product level, TES can reduce heat losses, improve heating/cooling performance and more. Some classic examples being the use of phase change materials (PCMs) to improve efficiency or cooling performance in cold shipping. Or with the use of zeolite to improve drying performance and efficiency dishwashers, by taking advantage of its thermochemical properties.

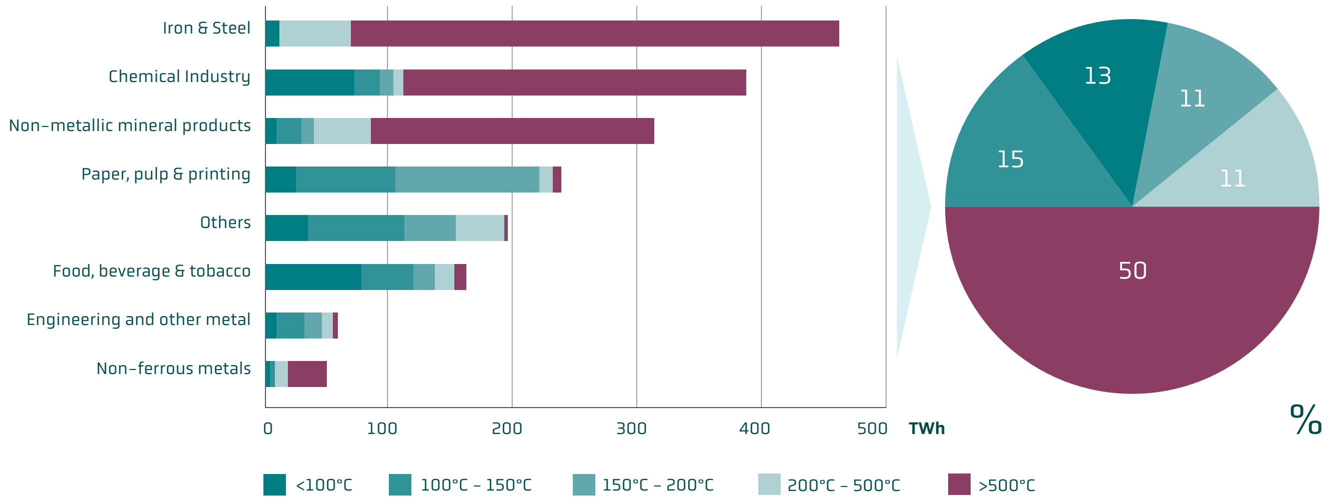
[1] Curtailment is the reduction of renewable power production, generally done when there is a lack of demand or capacity to transmit the power to the demand.

At the process level, larger systems can enable the utilization of waste heat and more. Like storing heat between batches or brewing steps in breweries – enabling increased energy savings compared to just direct electrification.

At the energy system level, it is the flexibility enabled by the large storage capacities of TES, at low costs. This contributes to even out imbalances over much longer periods of time, i.e., days instead of hours. This helps to reduce curtailment of renewables, by adding flexible demand for electricity. The large storages can also increase the utility and efficiency of other energy producers, especially combined heat and power plants (CHP), as described in the case: *Thermal energy storage for flexibility in the energy system.*

### 4. Lower dependence on scarce resources

There are other ways of adding flexibility to the energy system and decarbonize process heat. Currently there is a large interest in both battery energy storage systems (BESS) and hydrogen. However, these technologies depend largely on both critical and scarce minerals. In comparison, most TES technologies rely on abundant materials, with common storage mediums being water, rocks, slags, ceramics, salts and the like. With the remainder, mainly being specialized, but common industrial components, i.e., heat exchangers, steel tanks, blowers, pumps etc. This benefit is largely externalized from the technology developers and asset owners – but it is clearly favourable to make TES the first choice, whenever possible. As it can reduce our collective reliance on scarce resources.



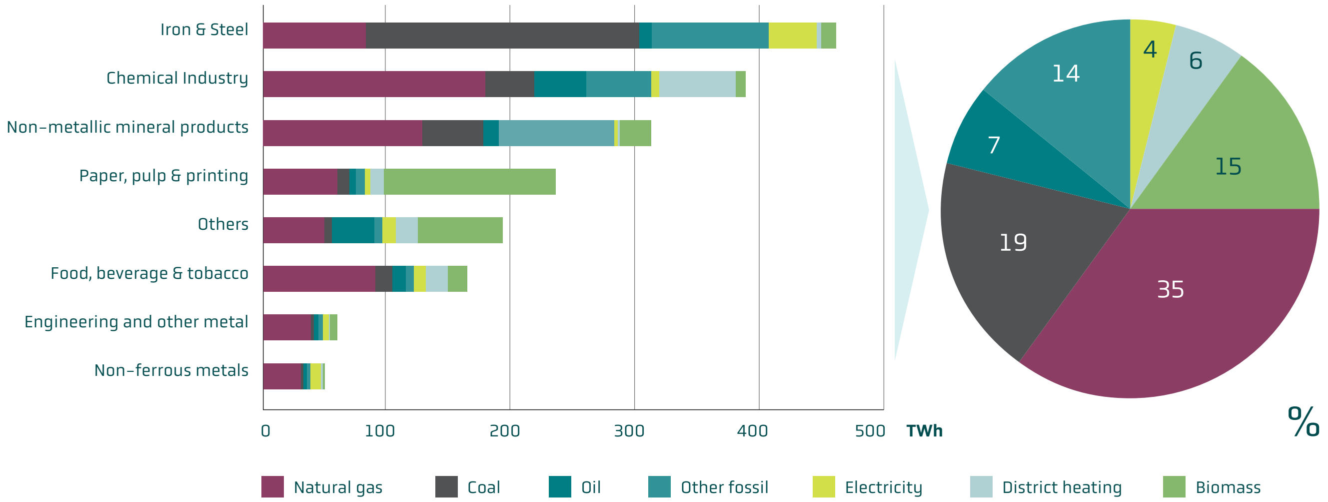




Figure 3: How industrial process heat is generated and at what temperature ranges across industries in EU27. Adapted from Agora Industry, [5].

## FOCUS AREAS FOR THERMAL ENERGY STORAGE

In the DaCES working group for thermal energy storage, we wish to highlight five areas that require special attention in order to accelerate and realize the numerous benefits of thermal energy storage in the energy transition

DaCES working group for thermal energy storage visits GreenLab Skive – a pioneer in developing and demonstrate the integrated energy system of the future.

### 1. Limited awareness of the existing scale and opportunities

There is far too little information and awareness of the large potential in thermal energy storage as an enabler for the energy transition. This is amongst the public in general, but also in industry and at the political level. This can also be observed in the absence of TES in national and EU policies, strategies, and roadmaps that are developed to support a sustainable energy transition where larger focus has been given to the uptake of hydrogen and batteries – whilst no such targeted initiatives exists' for TES.

To increase awareness, it is recommended to systematically involve thermal energy storage in energy system models and analysis. TES should be treated on equal footing with other storage/flexibility technologies such as, hydrogen and batteries. This applies to all levels, from regional to national, European and international energy system models. Currently most established energy system models do not include TES, in their assessments. For example, IEAs Global Climate and Energy models does not include TES [20]. Overall, the energy system effects of utilizing TES in making future industrial electrification flexible, deserves further analysis.

### 2. Structural issues for financing high temperature thermal energy storage to sufficient scale

All good technical solutions need to be financed, and these costs are largely depending on how risky the project is assessed to be. For energy assets, it broadly require dealing with three types of risks: technical, financial and market risks

Thermal energy storage is a capital-intensive technology that has major up-front costs, which is a challenge, especially when considering that it is still a relatively new technology with few large-scale deployments across the world. The business cases generally rely on recovering the high upfront costs through reduced energy expenses over a period of 7 to 15 years. Even if strong business cases can be found, the technological risks in the large-scale pilot systems are a challenge for widespread adoption of TES. Access to financing from banks and institutional investors requires guarantees of lifetime and performance that are very hard to impossible to provide for maturing/novel technologies. More risk-seeking investors have a much higher cost of capital, which in turn can kill the business case for thermal storage. Inherent market risks also exist, as the business cases largely rely on a combination of energy price volatility and provision of sustainable energy. Other technologies, such as, batteries/interconnection etc., contribute to reducing price volatility and thus diminish the business case. The overall market size could also be diminished with reduced price volatility. However, the fundamental business case is strong, as the cost of capacities are inherently lower than competing technologies.

Thermal energy storage is thus a case of the classical first-of-a-kind (FOAK) puzzle, where the first few much-needed large scale plants have proven challenging to finance. Neither venture capital (VC), end-users, nor institutional investors will fund the high up-front costs — even with off-take agreements — since the risks are deemed too large. For these technologies, a significant part of benefits is also externalized or non-valorised, e.g. reduced dependence on critical minerals etc.

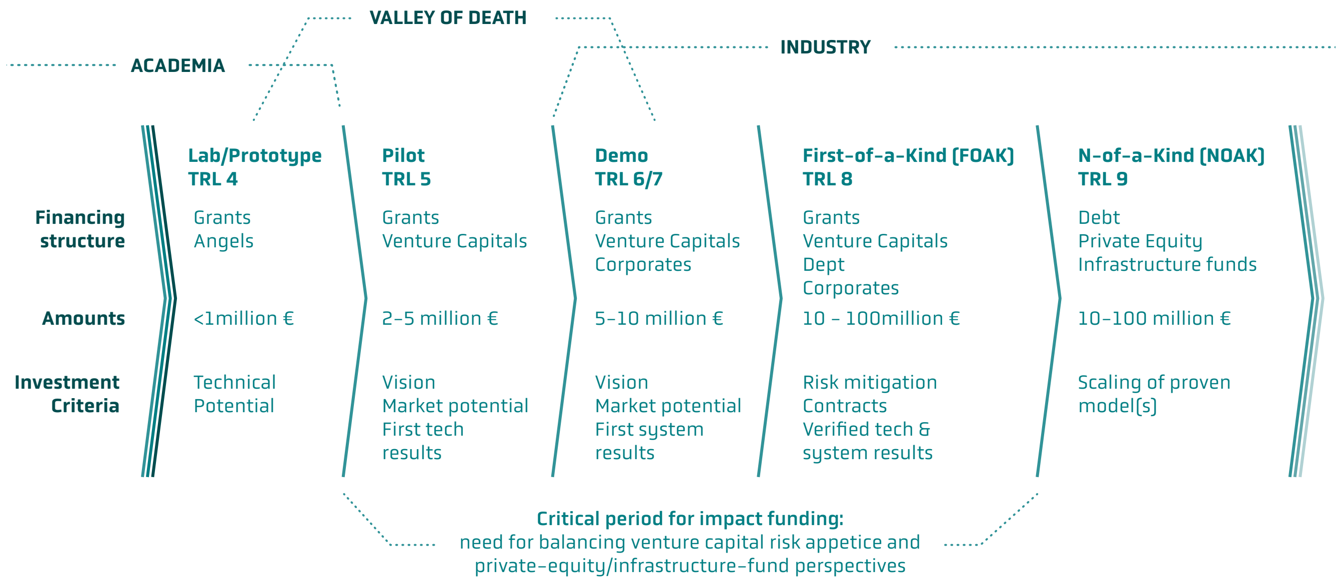



Figure 4: The typical funding amounts for each Technology Readiness Level (TRL) and highlights the large need for risk willing capital in TRL 6-9.
Adapted from Climentum Capital, [22]

In addition, the investment size of these assets, especially for industrial applications, are generally at the lower end of what is attractive for investment management funds. The burden of due diligence and administrative overhead is too large, relative to the total investment for these smaller assets. These assets typically "only" represent an investment of a few tens of millions of euros.

To solve this FOAK issue, it is necessary to reduce the technical and market risks, as this will support the reduction of the financial risks. This, however, all hinges on the awareness of the technical opportunities. And for industry, not to expect other energy technologies, such as hydrogen, biogas and similar, to solve their decarbonization and energy cost competitiveness issues.

### 3. Limited amount of test facilities and capacity is bottlenecking development of high temperature TES

The development of high-temperature thermal energy storage (HT-TES) for industrial process heat or power generation is hampered by a scarcity of advanced testing and validation facilities in Europe. Innovators require specialized test beds to evaluate new storage materials and components under realistic cycling conditions at temperatures of several hundred degrees Celsius. Currently, only a few labs and pilot sites can host such experiments, creating a bottleneck for scaling up prototypes to market-ready systems.

European research stakeholders have highlighted the need for independent TES materials testing institutes and demonstration sites. Establishing these would enable researchers and companies to demonstrate the reliability, durability, and safety of HT-TES technologies.



The market has diverse needs in terms of cost, temperature ranges, capacities, and integration considerations. This drives the demand for cost-effective performance across all scales of the systems. Future development must address these needs, from materials to components and their integration into systems that can decarbonize process heat with economic benefit

More specifically, efforts should focus on:

(A) Long-term performance testing under various cycling regimes.
(B) Development of new high-temperature storage materials with higher energy densities and stability.
(C) Improving heat exchanger designs for faster charging and discharging.
(D) Conducting more material testing of container materials, especially for corrosion at high temperatures, various flows, and pressures.
(E) Investigating mechanical properties after thermal cycling, e.g. thermal expansion rates, for both storage, component, and container materials.
(F) Digitalization of thermal energy storage to support smart integration, control, monitoring and optimization of TES within industrial and end-user processes.

As evident from the above, there is a significant opportunity to invest in shared high-temperature test facilities and programs. This will accelerate EU innovation and reduce the time-to-market for industrial TES solutions. It will also train engineers in designing, developing, and operating high-temperature TES systems, addressing a skills gap in this field.

### 4. Missing long-term support for demonstrators is slowing uptake by large commercial players

The investigation of long-term performance of any TES technology — over multiple years — is central to its adoption by large commercial players. However, securing funding for such long-term testing is challenging, as most R&D projects are structured around short 3-4 year timelines. These periods are often consumed by planning, design, construction, and commissioning of demonstrations, leaving minimal time for the critical test and validation phases — undermining the very purpose of building demonstrators in the first place.

After the end of the project, knowledge institutions have to move on to new projects, since they no longer have a way to cover their expenses for the researchers and operating costs. In addition, many funding programs have strict rules regarding depreciation of assets, that makes it harder to keep the demonstration running after the end of the project period, even if the costs for operation and maintenance could be found.

Also, most R&D programs do not cover operating costs even during the project period. Incentives for valorising the output from demonstrators, are explicitly removed: Any income from a demonstrator would normally have to be offset by a reduction in the grant. While such rules clearly exist for good reasons to discourage unfair competition and illegal state aid, they complicate and may hinder long-term success of large-scale demonstration of thermal energy storage technologies.

### 5. Lack of clear plans for the phase out of gas for process heat is delaying electrification efforts and uptake of TES by industry

The strong political commitment towards phase out of gas for process heat is essential for a successful transition to clean energy systems. This is true for decision-makers in industry: when the choice for heating source no longer includes natural gas, the question must be reformulated in terms of which available or upcoming technology is best suited as a replacement. Instead of asking when, or even if, a decreased reliance on natural gas should be sought after. The strength of having clear decarbonization goals for phase out of gas transcends to research as well. The relevant problems facing industry often inspire or shape research projects. A project that investigates the techno-economic potential of an industrial site would have a very different scope of analysis if a known date for phase-out has been given, or if clear carbon taxes with known values have been set.

# *Case 1*

## THERMAL ENERGY STORAGE FOR FLEXIBILITY IN THE ENERGY SYSTEM

Høje Taastrup Pit Thermal Energy Storage is the first "short-term" pit thermal storage system with a unique business model. The 3,300 MWh storage system increases existing CHP-plants efficiency and generating flexibility, whilst providing annual economic benefits of DKK 5–7 million.

More information:
www.planenergi.dk
Geoffroy Gauthier, Team Manager, PlanEnergi

Large-scale thermal energy storage offer significant environmental and economic benefits by coupling the heating and electricity sectors, particularly in energy systems with many different energy production units.
The Høje Taastrup pit thermal energy storage (PTES) system illustrates this potential by creating flexibility for the power and heating systems across the entire Copenhagen metropolitan area, contributing broadly to the energy transition of the capital's energy system.

PTES have generally been designed for long duration storage of heat, generally inter-weekly storage. However, the Høje Taastrup PTES is unique in mainly targeting intra-weekly storage. This enables the combined heat and power plants (CHP) to focus on peak power generation and reduce the use of peak gas boilers. Simulations show a potential of reducing peak gas boiler usage by 24 GWh yearly and increasing the heat generated by CHPs by 25 GWh yearly. Simply put, the storage enables CHPs to store the excess heat generated, when focusing on meeting the peak power demand.

The PTES is charged with heat produced by four large CHP plants (with a total capacity of 2,050 MW) and three waste-to-energy plants (with a combined capacity of 400 MW) through the extensive transmission network of the greater Copenhagen area. The stored heat is then discharged into the local district heating network in Høje Taastrup, which helps to reduce the peak load production of the local gas boilers (1,900 MW). During discharge, cooler return water is directed to the bottom of the storage, while hot water is distributed from the top via a network of pipes to customers in Høje Taastrup.

The PTES has a storage volume of 70,000 $m^3$, a charging and discharging capacity of 30 MW, and an energy storage capacity of 3,300 MWh. According to design simulations, this system is expected to generate an annual economic benefit of DKK 5–7 million for the district heating networks in the Copenhagen metropolitan area [23].

### Financing, ownership and business model

A new business model underpins the successful implementation of the PTES. VEKS, a municipality-owned heat transmission company, and Høje Taastrup Fjernvarme, a consumer-owned heat distribution company, jointly own the PTES. VEKS has secured the rights to use the storage for 20 years, by providing annual compensation. A cooperative agreement ensures that Høje Taastrup Fjernvarme handles the daily maintenance and monitoring of the PTES.

The financial benefits of the PTES are distributed among its stakeholders according to their share of the economic advantages. Benefits have been evaluated before the project implementation by using Balmorel, a complete model of the energy system of the greater Copenhagen area. Transmission companies (VEKS, CTR/HOFOR) account for 56% of the benefits, primarily from savings on peak-load demand, as these transmission companies are also the owners of the peak-load production units in the distribution district heating network of Høje Taastrup. The CHP producers share 28% of the benefits, while the three waste-to-energy plants account for the remaining 16%. All benefitting partners contribute a fixed annual fee for 20 years to ensure the storage's availability and long-term functionality. The greatest operational change is for the CHP producers, as the storage enables much more flexible operation of their assets and focus more on the electricity markets.



Figure 1: Picture of the PTES in Høje Taastrup under construction.

The benefits for the waste incinerators mainly occur during the summer, when waste still needs to be burned, even when the heat demand is low. There, the storage acts like a daily storage, evening out the daily variation of the heat demand (mainly for domestic hot water). As such, the storage is partially supplementing the short-term Tank thermal energy storages (TTES) of the greater Copenhagen area, although these storages have a charge/discharge capacity about ten times higher than the maximum charge/discharge capacity of the PTES. Those tanks however, discharge into the district heating transmission network, which lessens their direct competition.

| PROJECT STATUS | IN COMMERCIAL OPERATION, SINCE FEBRUARY 2023 | |
|---|---|---|
| Technical parameters | Max charging/discharging capacity [MWth]: | 30/30 |
| | Max energy storage capacity [MWh]: | 3,300 |
| | Response time [s]: | 3,600 (0.5 MW/min) |
| | Round-trip efficiency [%]: | 87% in year 1 |
| | | 89% in year 2 |
| | Expected to reach 90-95% in the following years as the soil heats up. | |
| | Storage lifetime [year]: | ≥ 20 |
| Economic parameters | Reference energy cost [€/MWh]: | 102 (electricity) |
| | CAPEX [€/kW]: | 405 |
| | OPEX [€/MWh]: | 69 per MWh capacity per year |
| | | 8.3 per MWh heat charged |
| | LCOE [€/MWh]: | - |
| | Payback time of the investment [years]: | 11.6 |
| Please note some values here are design figures.<br>For more information, find the detailed business case presented in IEA-ES Task 41, [24] or the performance analysis in [23] and [25]. | | |

Table 1: Basic information about the PTES in Høje Taastrup.

## *Case 2*

# GREENHOUSES HELP STABILIZE THE GRID THROUGH VIRTUAL POWER PLANTS

SCANGRID and San Electro Heat have developed a smart heating solution that allows greenhouses to electrify at lower cost. By using existing pipes and tanks as a thermal energy storage, greenhouses can absorb excess renewable electricity and provide valuable grid services, supporting the energy transition. But it requires a specialized e-boiler and smart control.

More information:
www.scangrid.dk and www.san-as.com
Carsten Vammen, Founder and Director, SCANGRID
John Baarsgaard Kristensen, Technical Sales, SAN Electro Heat

Greenhouses can become large flexible energy consumers and help keep the balance in the power grid whilst lowering their energy costs. This is enabled by SCANGRID virtual power plant and San Electro Heats' e-boilers. Greenhouses are significant energy consumers, primarily for heating, which has traditionally been provided by natural gas, oil, and biomass. Since the late 2010s, there has been a substantial increase in the use of district heating, but this option is unavailable in many regions. Electric heating is another option, but without storage, it exposes greenhouses to volatile electricity prices. Fortunately, greenhouses can use their large watering tanks and systems as heat batteries, storing intermittent but cheap electricity as heat.

Moreover, on the power grid, power production and consumption must match every second. With increasing shares of uncontrollable energy generation, there is a growing need for controllable consumption. This creates an opportunity for flexible energy consumers, such as greenhouses with storage.

**This requires:**

1. An electrical heater designed to operate at much higher power, as the same heat demand needs to be met in fewer hours.
2. Smart control of the heating to respond to the owners' and the grid needs, as lower energy costs are secondary to a business's core operation, plant cultivation.

Figure 5: CAD vizualization of the large e-boiler.

The two companies, SCANGRID and San Electro Heat have jointly developed a heating solution for large Danish greenhouses. A key design feature is the flexible grouping of the e-boiler's heating elements, enabling efficient operation at many different power levels, depending on grid needs.

Through aggregation in SCANGRID's virtual power plant, greenhouses can participate in most markets for balancing and ancillary services. This further supports the energy transition, whilst reducing energy costs, without increasing the complexity for the owners.

"Greenhouses with e-boiler based heating systems, have a built-in advantage, in that they can balance the power grid, by using their pipes and tanks as a form of energy storage. They can absorb large amounts of excess electricity from photovoltaics and quickly stop their usage, when a cloud blocks the sun. This is how greenhouses can help stabilize the power grid, by offering both balancing services and energy storage – and it is one of the finest examples of replicable, successful sector coupling in the energy sector."

as explained by Carsten Vammen from SCANGRID.

## *Case 3*

## SUSTAINABLE PROCESS HEAT FOR WORLD LEADING DAIRY PRODUCER

**Molten salt energy storage from Hyme is now much closer to providing large scale process heat continously all year round. With backing from EUDP, Hyme has built and tested a 1.2 MWh demonstrator and is now developing its first commercial offering. In collaboration with Arla, Hyme is designing one of the world's largest industrial thermal energy storage systems, at 40MW/200MWh, to decarbonize heat supply at Arlas Holstebro facility.**

More information:
www.hyme.energy
Karine Blandel, Business Development Lead, Hyme

Hyme, established in 2021, with ~30 employees, is developing a molten salt energy storage based on hydroxide salts, as it enables high energy densities[4] . The company completed the construction of their industrial demonstrator (1.2 MWh of storage capacity) in April 2024 and has been testing and upgrading it since then. This project received the support of EUDP and aims at fully demonstrating and derisking the capabilities of Hyme's commercial product. Hyme is now developing their first commercial offering. This has required narrowing the technical scope, by further focusing on the end-customer needs and finding the right partners for the first units. This has led to focusing on reliability, reducing CAPEX and initially targeting a slightly lower temperature range. This focus on developing their commercial products comes after years of intensive research into fundamental technology, which was necessary to prove the technology vision.

Hyme is currently collaborating with Arla, a leading dairy producer, to develop the world's largest industrial TES to fully decarbonize the heat supply at Arla's milk powder facility in Holstebro, whilst reducing energy costs significantly. As the system has large upfront costs, and inherently carries FOAK-risks, they are seeking EU funding, to reduce the financial risks – stressing the continued need for support.

The unit is planned to store 200 MWh and deliver steam at ~220 °C continuously all year round. Its large storage capacity and small footprint made molten salt an attractive choice for this application. Comparatively, scaling capacity is simple – it is mainly increasing the size of the storage tanks. Whilst containerized solutions, like BESS, scale less space efficiently[5].

The site is particularly attractive due to the high penetration of renewables and available capacity in the local grid. Which is paramount, as the underpinning business case, relies on charging a full day of energy usage in a handful of hours - by using the charging capacity of 40 MW.

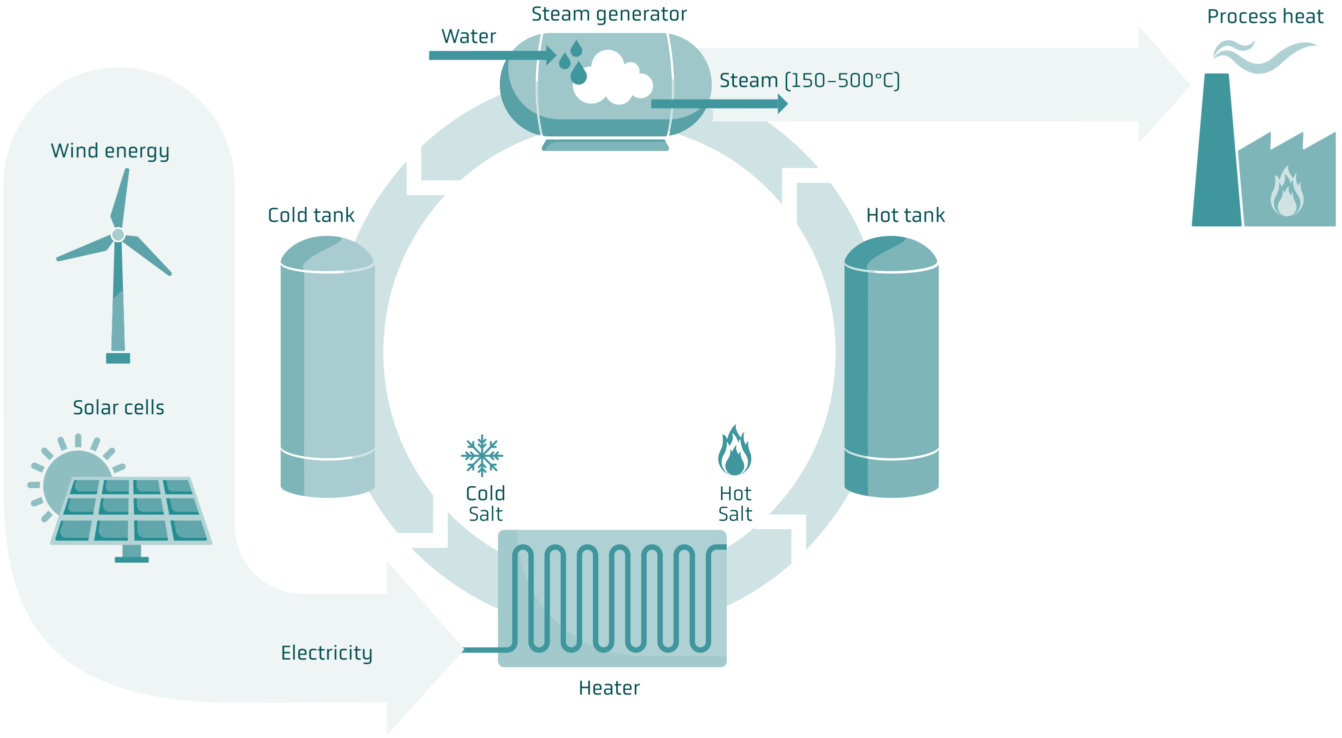



Figure 6: illustration of Hymes energy storage concept. Temperature ranges are optimized to each specific case.

[4] Hydroxide salts have high specific energy densities, i.e., how much energy required to raise it 1 degree. This enables storing more energy, in a manageable temperature range.
[5] For example, 200 MWh BESS would require 32-65, 20-foot containers, with limited ability to use vertical space.

Visit at the research laboratories for electrochemistry and thermal analysis at DTU Energy with DaCES thermal energy storage working group, November 2024.

# DaCES WORKING GROUP FOR THERMAL ENERGY STORAGE

**Adam Rasmus Jensen**, Senior Researcher, DTU Construct

**Adriano Sciacovelli**, Professor, DTU Construct

**Ahmad Arabkoohsar**, Professor DTU Construct

**Anders Larsen Reichhelt**, Business Developer, Andel

**Christian Nodskov Duus Nielsen**, CTO, ATE

**Claus Schøn Poulsen, Director**, Danish Technological institute

**Dan Kofoed**, Project Manager, Heliac

**Erik Gydesen Søgaard**, Emeritus, AAU Kemi og Bio

**Fredrik Haglind**, Professor, DTU Construct

**Geoffroy Gauthier**, Team Leader, PlanEnergi

**Gerald Englmair**, Associate Professor, DTU Construct

**Hans Aage Hjuler**, Lab Manager, Copenhagen Atomics

**Ioannis Sifnaios**, Researcher, DTU Construct

**Jakob Hærvig**, Associate Professor, AAU Energy

**Jianhua Fan**, Associate Professor, DTU Construct

**Jesper Nielsen**, Senior electrical Specialist, Innovation & Concepts, Vestas

**John Baarsgaard Kristensen**, Technical Sales, SAN Electro Heat

**Karine Blandel**, Business Development Lead, Hyme

**Mads Emil Dalhoff Greisen**, Consultant, Niras

**Mads Johnbeck**, Product Engineer, FORCE Technology

**Ming Chen**, Professor, DTU Energy

**Morten Herget Christensen**, Team Manager, Danish Technological institute

Paride Gullo, Associate Professor, SDU

**Per Alex Sørensen**, Project Manager, PlanEnergi

**Peter Munk**, Technical Manager, SAN Electro Heat

**Peter Estacio Franco Oxtorp**, Chief Consultant, Andel

**Thomas Steenberg**, Director, Copenhagen Atomics

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