

Industrial Thermal Energy Storage

current status and developments

Brabant Energy Leaders, 2024-07-11

Robert de Boer / TNO

[Start presentation](#)

Agenda



1. Introduction / TNO
2. Background on industrial heat demands
3. Energy Storage in a sustainable energy systems
4. Current status of industrial TES
5. Applications of TES
6. New developments of TES
7. SDE++ subsidy scheme
8. Summary

TNO

Dutch National Organization for technical research

- Founded in 1932
- About 3600 employees, of which 2100 researchers
- 14 Locations in the Netherlands, 560 Meuro turnover

6 units:



Topics in Energy & Materials Transition (EMT)

- Renewable energy (PV, wind)
- CO₂ neutral built environment
- CO₂ neutral industry
- Renewable fuels & hydrogen
- Subsurface
- Energy transition studies



TNO – EMT: STIP (Sustainable Technologies in Industrial Processes)

Heat

- Industrial heat pumps
- **Industrial heat storage**
- Industrial electrification
- Industrial energy efficiency

Liquid separation

- Membrane development
- Efficient separation processes

Gas separation

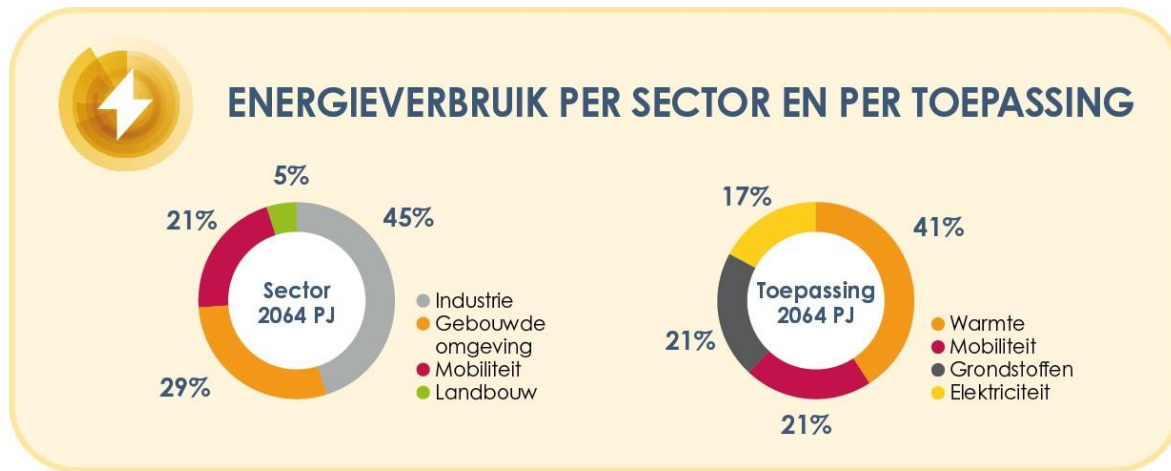
- Sorption enhanced processes
- CO2 capture

Clean hydrogen

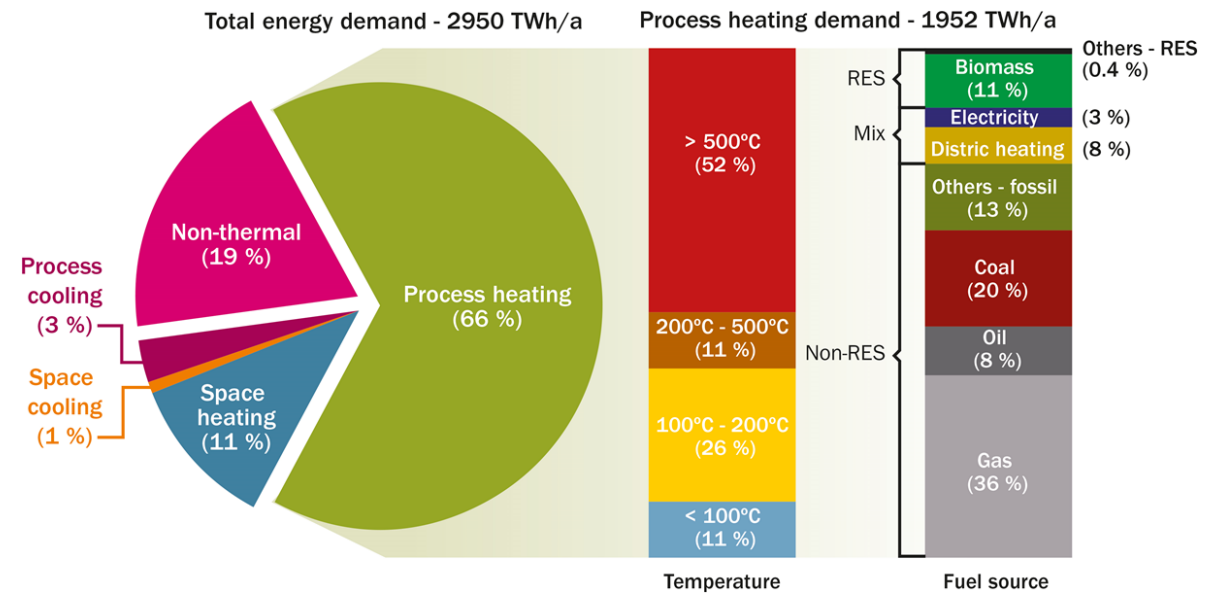
- PEM electrolyzers
- Solid oxide electrolyzers



Industrial energy use

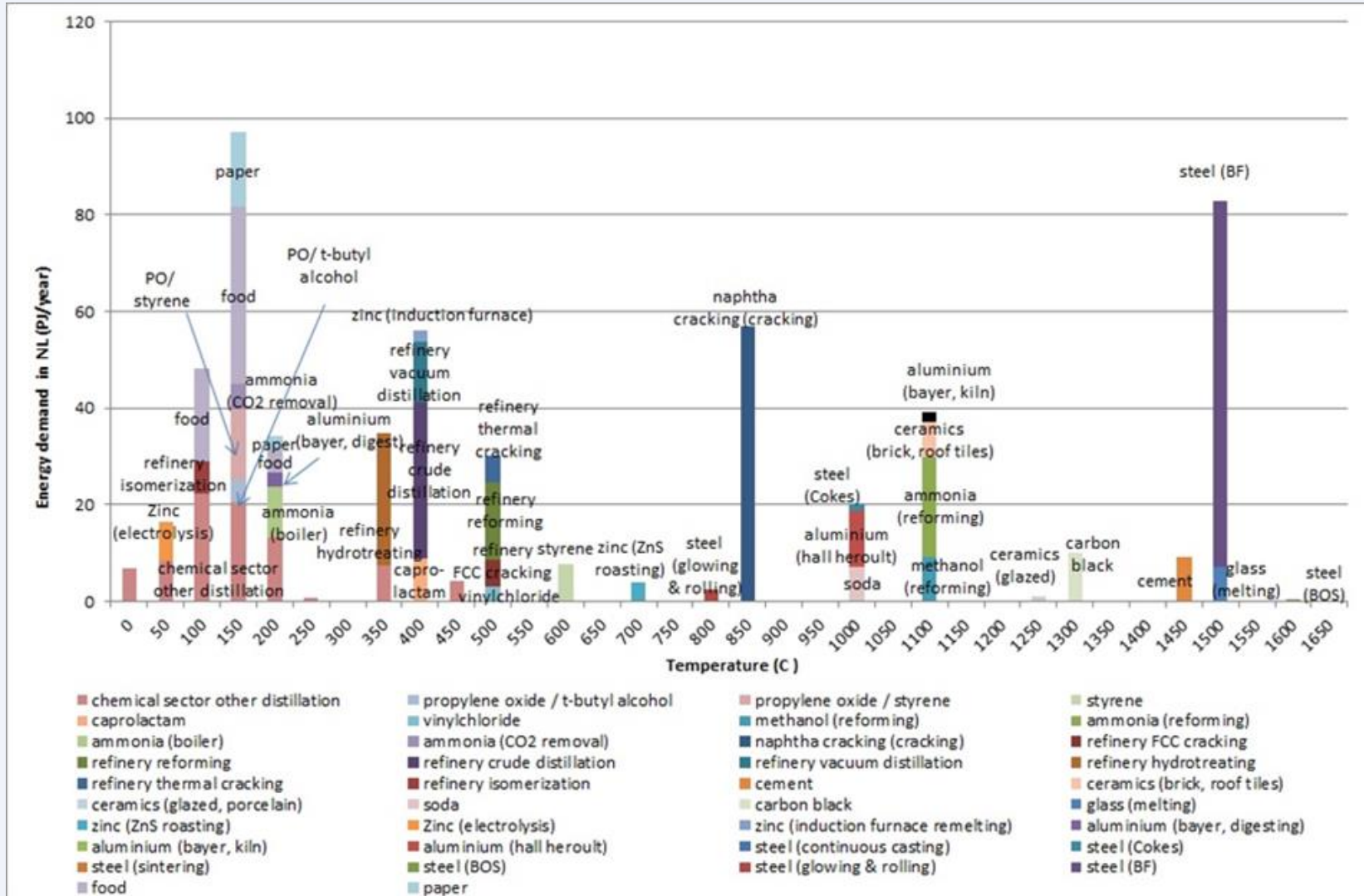


Source EBN / NL 2024



Source Whitepaper IHP / EU 2020

Industrial heat demand



Industrial Thermal Energy Storage

Why industrial heat storage?

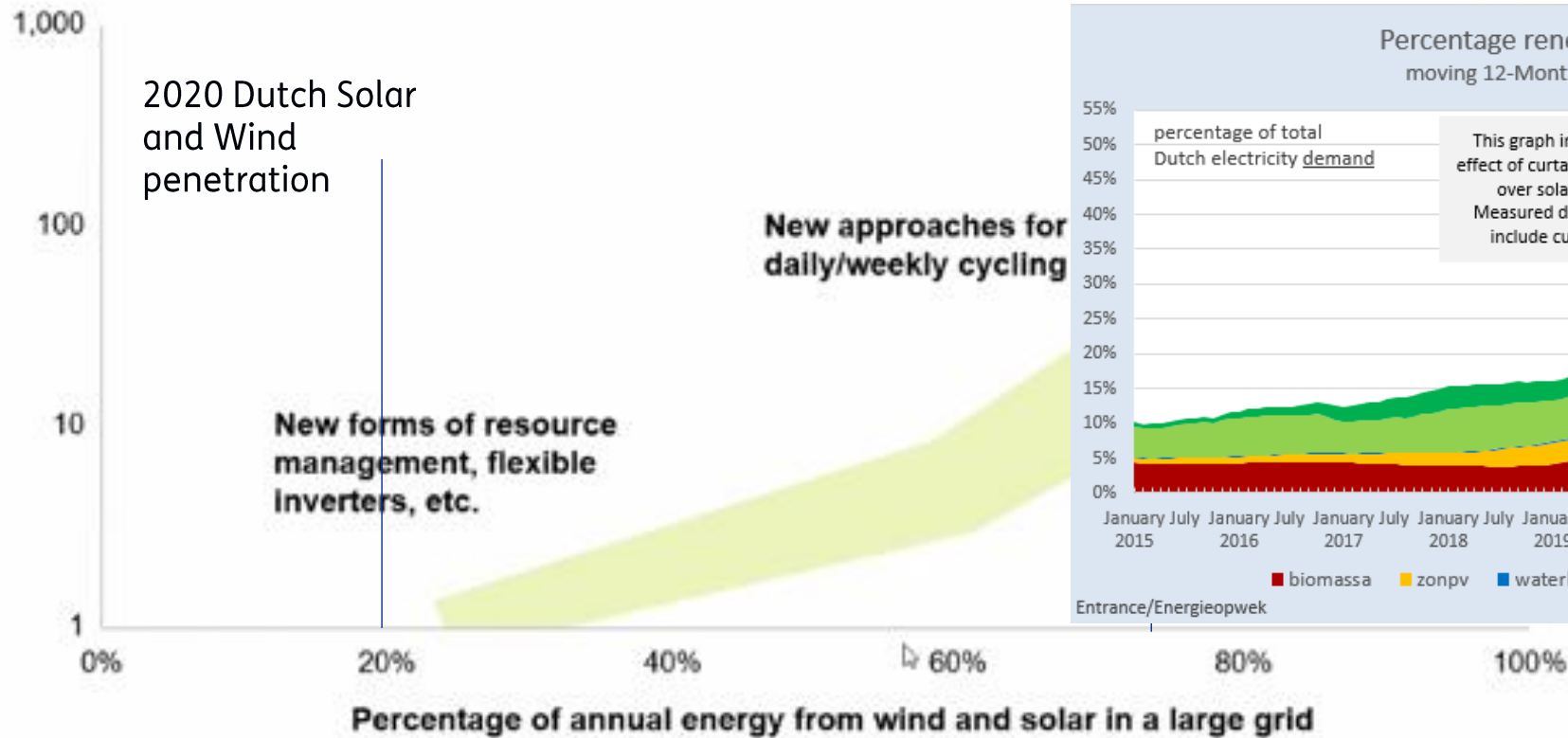
- Batch heat recovery
- Limited conversion power / peak shaving
- Backup storage
- **Integration of (fluctuating) renewables for electrification of process heat**
 - **Direct electric heating, e.g. e-boiler**
 - **Heat pumps & MVR**

Different storage technologies under development

- Sensible – molten salt, solids, ...
- Latent – various PCM for steam applications
- Thermochemical – metal fuels

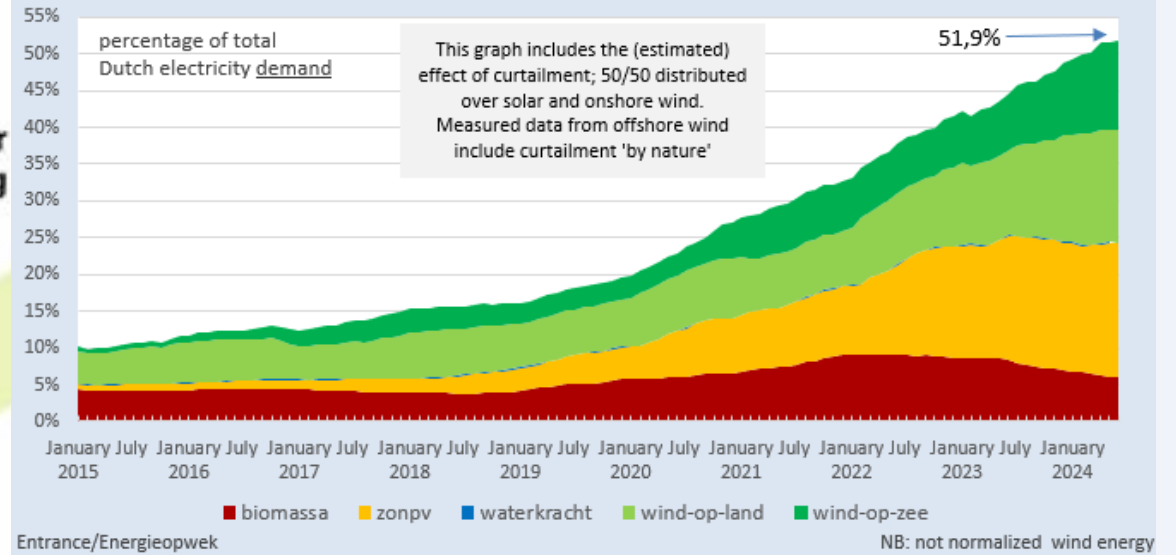
Adoption Curve for longer flexibility duration accelerates at 60-70% RE penetration

Storage duration, hours at rated power



Source: Advanced Research Projects Agency-Energy

Percentage renewable electricity in NL moving 12-Months average until June 2024



The Application Gap for Thermal Energy Storage

Four Zones of energy storage:

Very short duration (less than 5 mins)

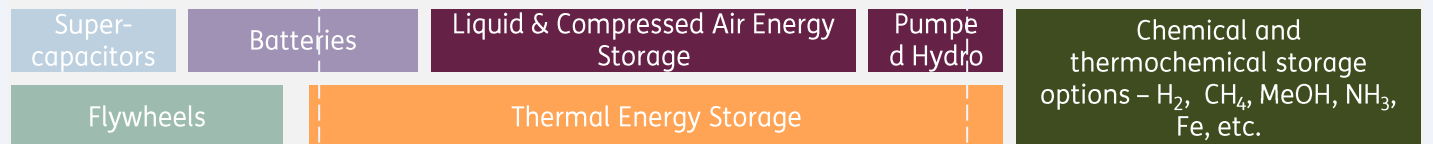
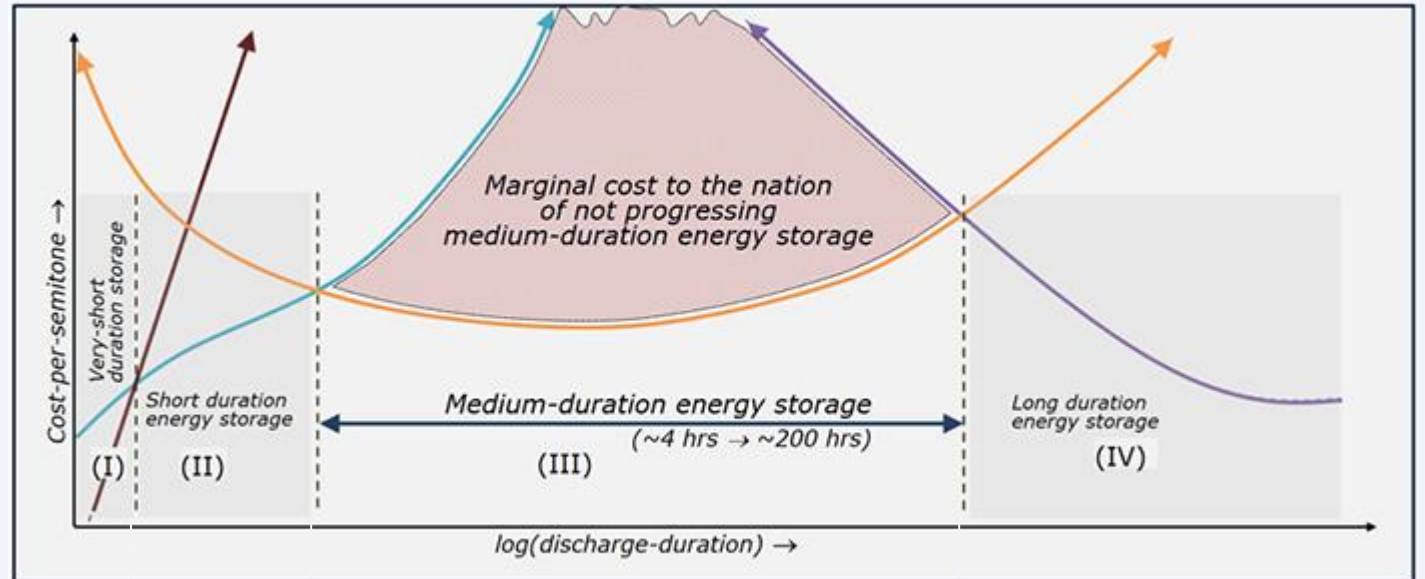
Short duration (5 min to 4 hrs)

Medium duration (4 to 200 hours)

Long duration (> 200 hrs)

LAES, CAES and Thermal Energy Storage can fill the medium-duration energy storage.


Source



Application of LAES and CAES are geared towards **electricity storage and grid support**.
 Application of Thermal Energy Storage is geared towards industrial **process environment and sector coupling**.

Supply - Demand matching

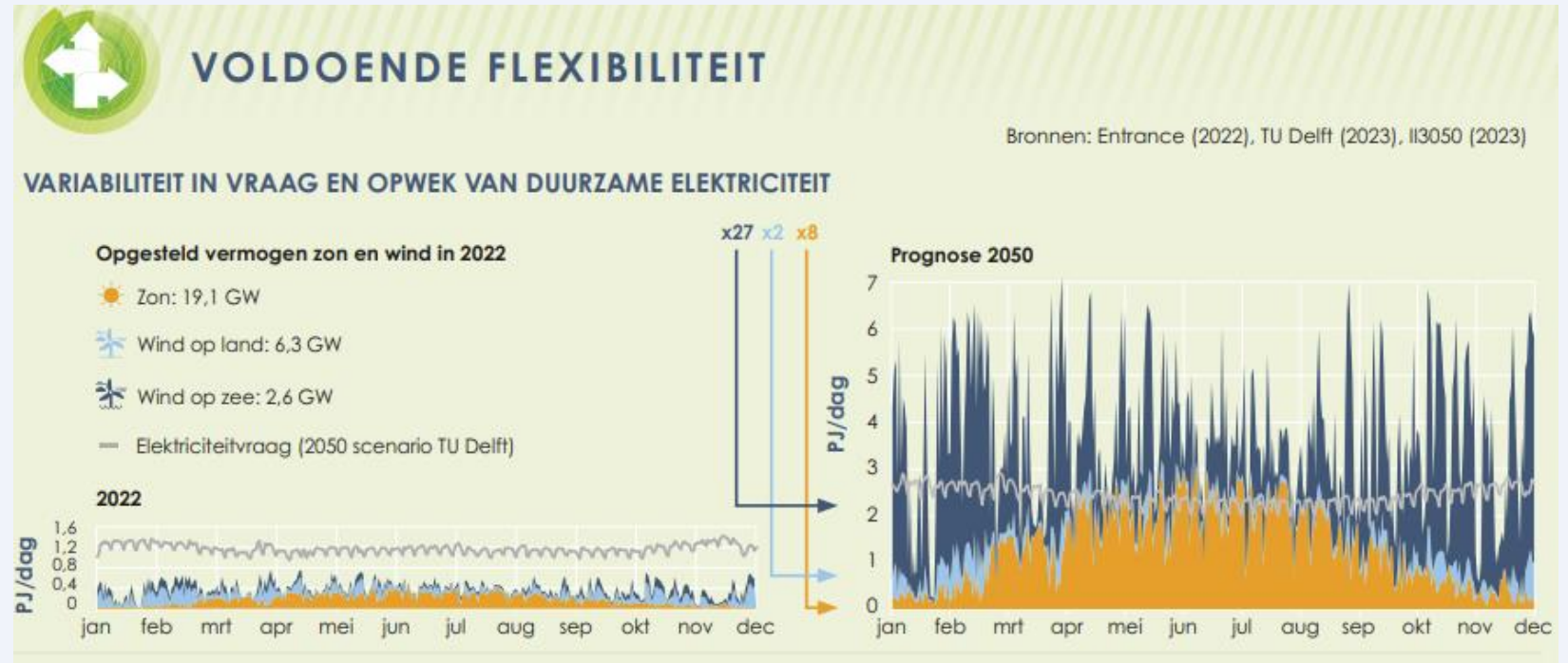
tki offshore energy
topsector energie



Flattening the Curve

door Thijs Verboon (Berenschot), Bart Visser en John Kerkhoven (Kalavasta)
1 november 2023

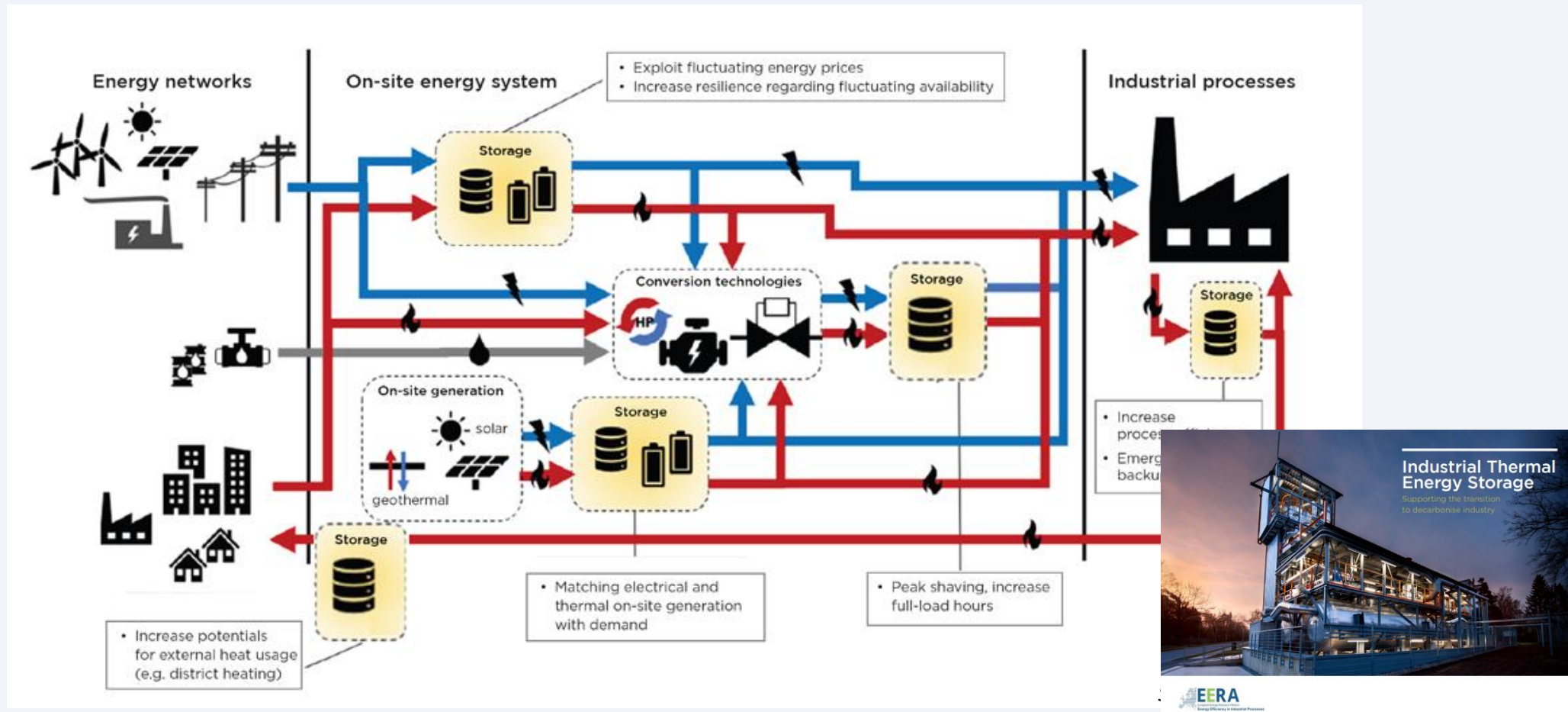
www.tki-offshoreenergy.nl



Source EBN, 2024

Thermal Energy Storage

- illustration of several classes of application of TES in future, fossil-free industries, with an active role in a renewables based power system



Thermal Energy Storage: Examples

IEA ECES Annex 30

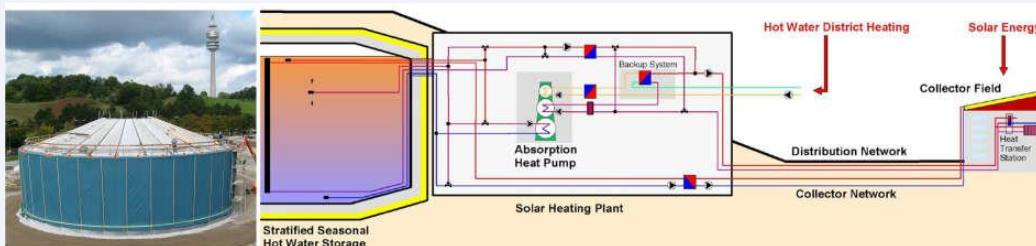
District heating and buildings



DK; pit storage; solar



NL; tank storage; CHP



DE; tank storage, solar



SE; PCM cold storage

Thermal Energy Storage: Industrial examples

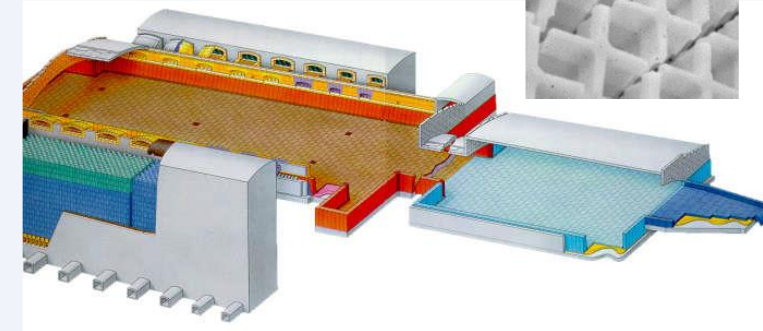
Power Plant / industrial



Steam accumulators



Cowper recuperators: Steel



Regenerators: Glass



2-tank molten salt



Phase Change TES: Industry → built environment

BEL

Recent TES examples

Sappi Maastricht
Electric boiler + TES (steam)



Papierfabricage bij Sappi in Maastricht. Het papier wordt gedroogd met stoom, waarvoor het bedrijf elektrische boilers gebruikt. Beeld Marcel van den Bergh / de Volkskrant

Brenmiller-ENI(It)
TES for flex-CHP



Kyoto -NorbisPark (DK)
TES for district heat



EnergyNest - Yara (No)
TES for steam grid balancing



PepsiCo - Eneco - Kraftblock (NL)
Electric heating + TES



New developments in TES

Organisations active in maturing technologies and markets for TES

- Long Duration Energy Storage (LDES) Council → all types of energy storage beyond Li-ion batteries
- EnergyStorage NL
- BVES (DE)
- European Association on Storage of Energy, EASE
- IEA –TCP- ES Annexes on specific TES developments and applications
- EERA European Energy Research Alliance: - Joint program on Energy Storage
- *HeatFlex (NL)*

... is a cost-efficient 24/7 heat decarbonisation solution

Levelized cost of heat (steat for selected technologies USD/MWh)

Technology equivalents

15-25

Heat pump with TES

is

HeatFlex

Future-proof Dutch heat-intensive process industry – the gateway to sustainability and economic growth –

Chemical
Paper
Food

Steel
Glass
Ceramics

Natural gas

New earning capacity

Green products, knowledge & Technology

TU Delft
PRO2TECH
AS4
Ministerie van Economische Zaken
van Klusmaat

TNO innovation for life

ChemistryNL

Catalyze

Utrecht University
TU/e

Institute for Sustainable Process Technology

topsector energie

and all industrial partners

HT-TES project overview

Company name	Headquarters	Level of commercialisation
Brenmiller Energy	Israel	Four commercial plants in operation in Italy, Brazil, USA and Israel (27 MWh)
Kyoto Group	Norway	Commercial demonstrator in operation in Denmark (18 MWh)
Eco-Tech Ceram	France	Three commercial plants in operation in France (total 9.3 MWh)
Energynest	Norway	Two commercial projects in Belgium (5 MWh) and Norway (4 MWh)
Rondo Energy	USA	First commercial project in operation in USA (2 MWh)
Polar Night Energy	Finland	First commercial plant in operation in Finland (8 MWh)
Build to zero	Spain	First commercial project under construction
Storworks Power	USA	Demonstrator in operation
Carbon-Clean Technology	Germany	Demonstrator in operation (1 MWh)
Malta Group	USA	Demonstrator in operation in the USA
1414 Degrees	Australia	Demonstrator of SiBrick in operation in Australia (1 MWh)
Kraftanlagen GmbH	Germany	Two demonstration plants in Germany (2 MWh and 20 MWh)
Alumina Energy	USA	First demonstrator in operation in the USA (450 kWh)
Antora Energy	USA	First demonstrator in operation in USA
MGA Thermal	Australia	First Demonstrator (5 MWth) under construction
Exergy3	Great Britain	First demonstrator in Scotland under construction (36 MWh)
Magaldi Green Energy	Italy	First demonstrator under construction
247Solar Inc	USA	Demonstrator under construction in USA (3.6 MWh)
Element16	USA	First demonstrator under construction in USA (1.5 MWh)
E2S Power	Switzerland	Pilot plant in operation in India (0.25 MWh)
Storasol / enolcon	Germany	Pilot plants in operation
Kraftblock	Germany	Pilot plants in operation (70 to 150 MWh)
Lumenion GmbH	Germany	Pilot project in operation in Germany (2.4 MWh). First demonstrator under construction in Germany (20 MWh)
Heliac	Denmark	Pilot plant: operated for 24 weeks in Denmark (0.5 MWh)
Sunamp	Great Britain	Pilot projects realised
Electrified Thermal Solutions	USA	No pilot plant yet
Hyme Energy	Denmark	No pilot plant yet
Kaaj Energy	Canada	No pilot plant yet
Pintail Power	USA	No pilot plant yet
Rpow	Spain	No pilot plant yet
Terrajoule Energy	USA	No pilot plant yet

CATALYST

Breakthrough Energy Catalyst and the European Investment Bank Announce €75 Million of Funding for Rondo Energy to Develop Industrial Decarbonization Projects Across Europe

With Rondo's first-of-a-kind projects, EU-Catalyst accelerates the widespread deployment of climate technologies that can cut emissions without a green premium.

By Breakthrough Energy on Jun 26, 2024



New Developments → TES solution providers

Sensible

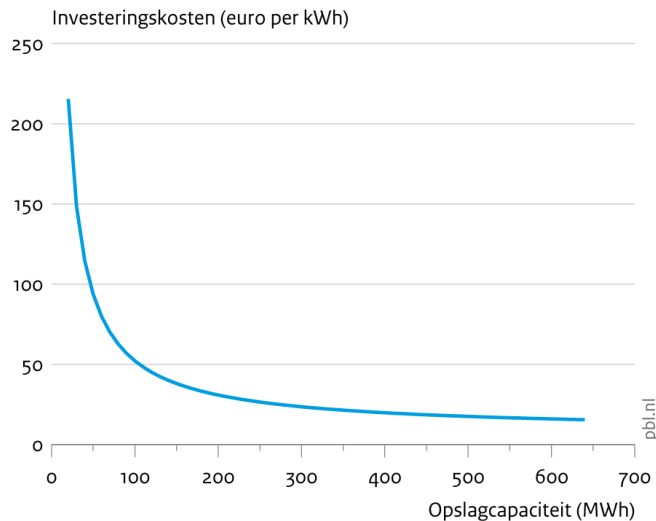
Latent

Thermochemical

SDE ++ 2024 HT-TES as a new category

- Stimulating innovative applications of technologies with low/zero carbon footprint
- In 2024 HT-TES introduced as a new category in SDE++

Geschatte investeringskosten voor thermische opslag op hoge temperatuur, 2023



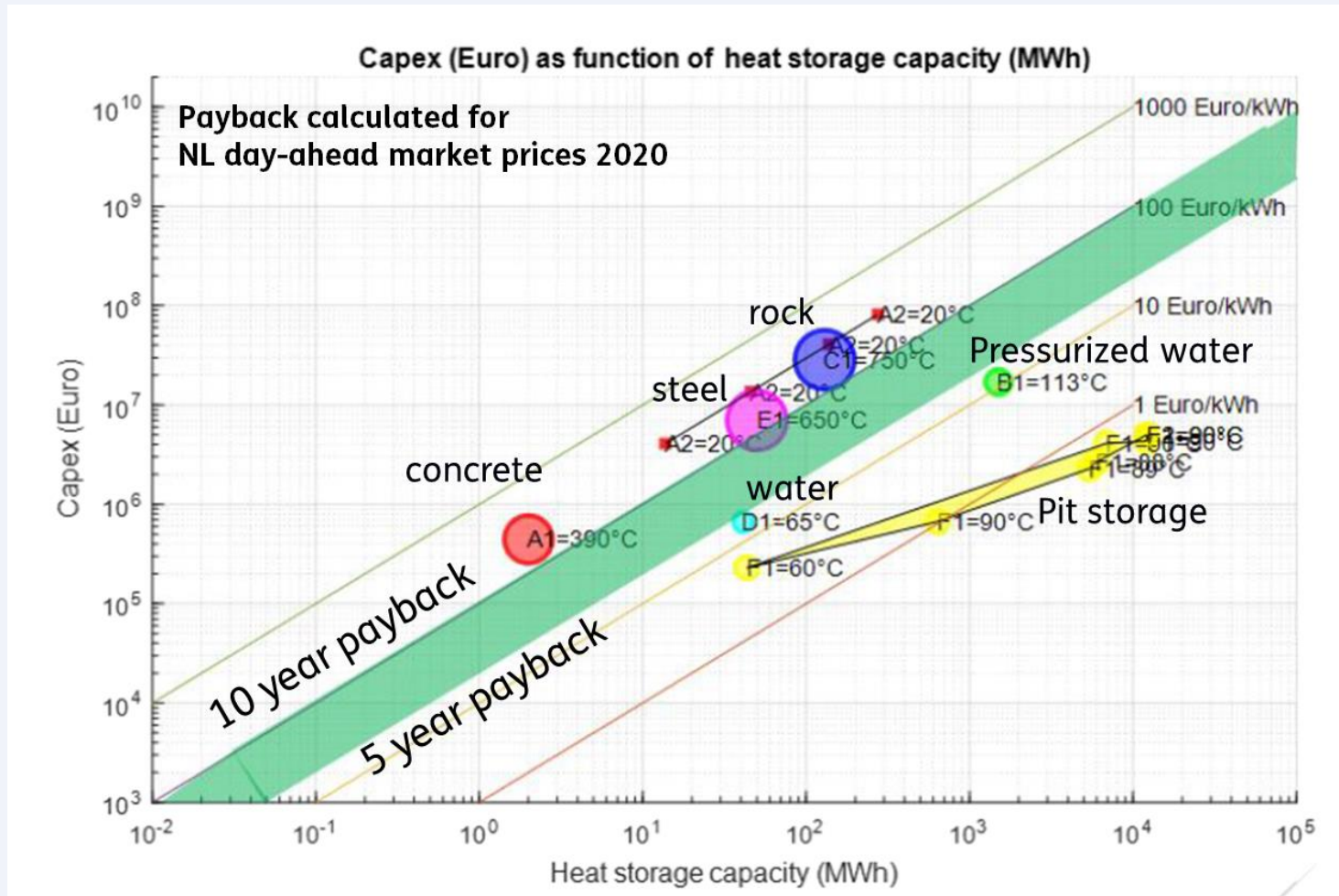
Bron: PBL

Tabel 11.7

Technisch-economische en subsidieparameters parameters voor hogetemperatuur-thermische opslag

Parameter	Eenheid	Advies SDE++ 2024
Inputvermogen	[kW _e]	19.737
Outputvermogen	[kW _{th}]	12.500
Vollasturen elektriciteitsgebruik	[uur/jaar]	3.300
Vollasturen warmtelevering	[uur/jaar]	5.000
Investeringskosten	[€/kW _{th}]	1.069
Vaste O&M-kosten - netwerkkosten	[€/kW _{th} /jaar]	297
Vaste O&M-kosten - onderhoud	[€/kW _{th} /jaar]	29
Variabele O&M-kosten	[€/kWh _{th}]	0,0339
Basisbedrag SDE++	[€/kWh _{th}]	0,1359
Looptijd subsidie	[jaar]	15

TES simple payback time analysis



Summary

- Industrial Heat is the dominant factor in the overall industrial energy consumption and CO2 emissions
- Electrification of heating systems effectively reduces CO2 emissions, using renewable E-sources
- Solar/Wind based Electricity system needs increasing energy storage capacities with increasing storage duration
- Electric Heating + Thermal Energy Storage in industry can provide flexibility, increase the share of RE, reduce CO2 emissions
- Increased level of development of novel TES solutions for industries, attracting investment capital
- Large variety in technical solutions for TES, targeting various applications
- Pilots and demonstrations of novel TES are emerging, supported by subsidies

Theme name

Place text here

Thanks for your attention

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