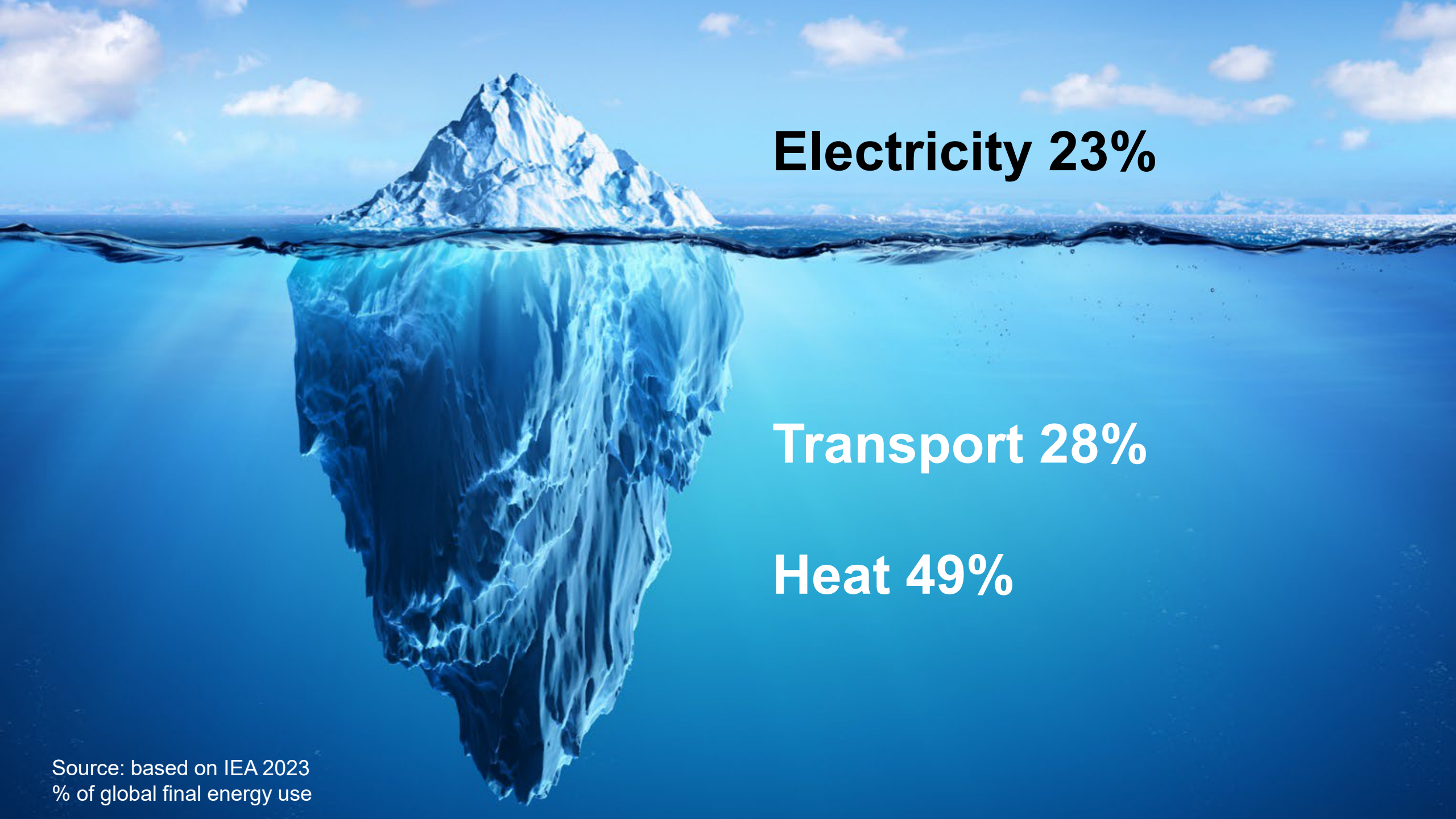
THERMAL ENERGY DAY

Budapest, 8 October 2025

Introduction

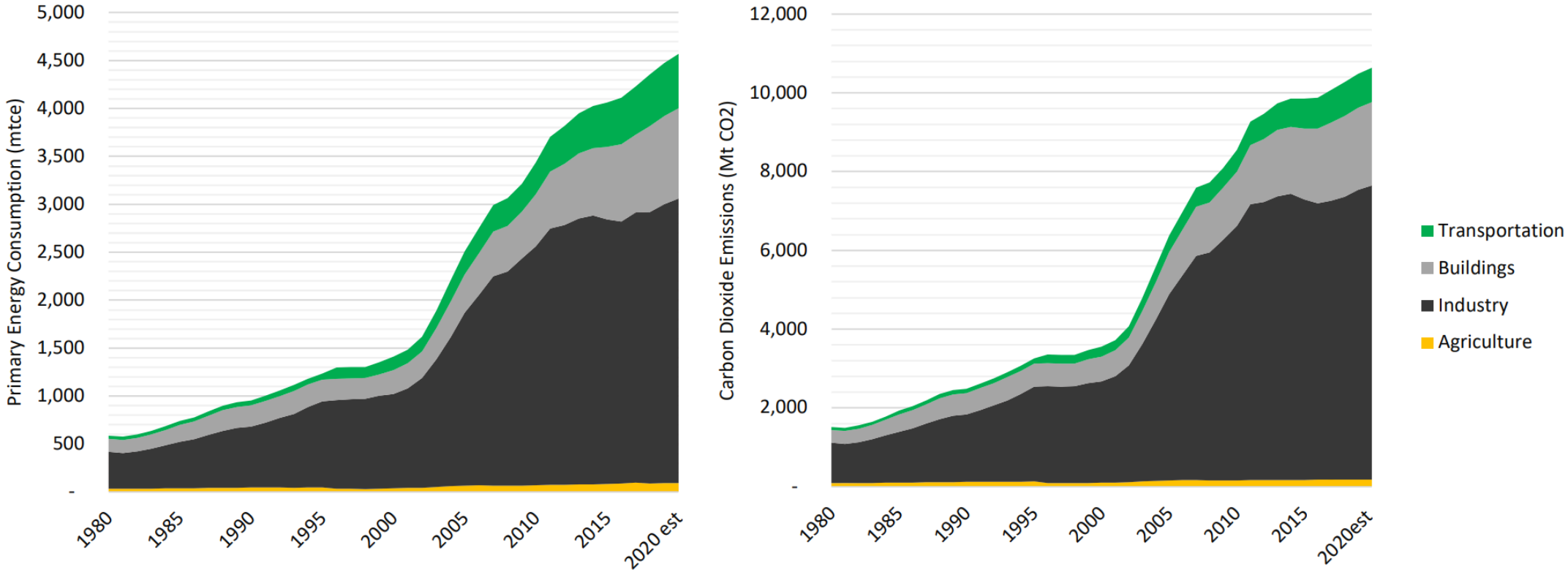
Jan Rosenow

Professor of Energy & Climate Policy at Oxford University



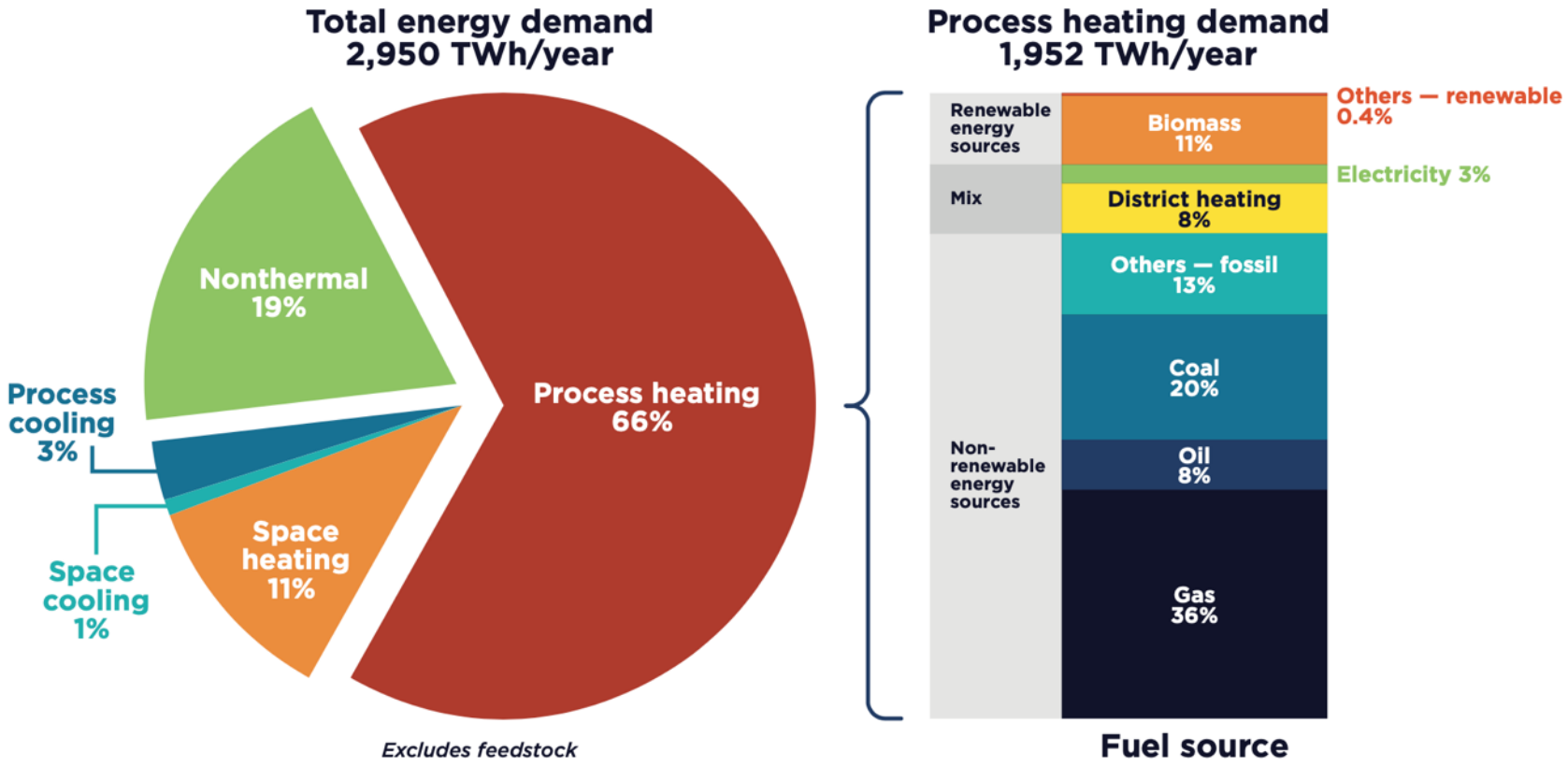
Source: based on IEA 2023
% of global final energy use

Industrial sector in China accounts for 65% of primary energy use and 70% of energy-related CO2 emissions



Source: Zhoe et al. 2022

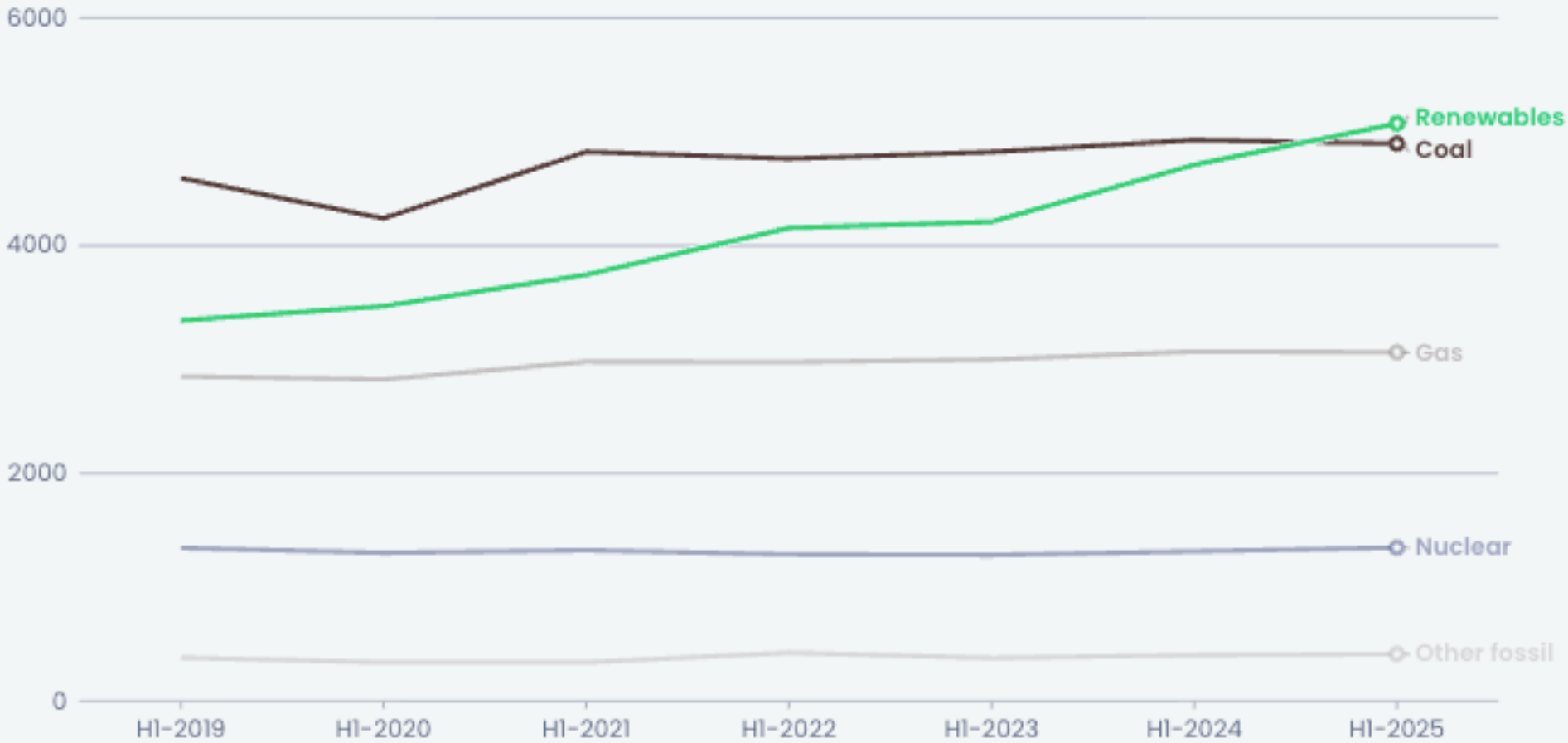
Most industrial process heat is fossil: Example EU with only 3% from electricity



Source: de Boer et al. 2020

Renewables produced more electricity than coal for the first time on record in the first half of 2025

Global generation, Jan-Jun of each year (TWh)



Source: Monthly electricity data, Ember

Renewables include wind, solar, hydro, bioenergy and other renewables, such as geothermal

EMBER

THERMAL ENERGY DAY

Budapest, 8 October 2025

Session 1

Market Signals and Infrastructure – Shaping the Thermal Energy Landscape

THERMAL ENERGY DAY
Budapest, 8 October 2025

Energy Markets in Transition: Power Thermal & Storage Outlook

Dr Stavros Skarlis

Research Senior Associate at Aurora Energy Research

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Energy Markets in Transition: Power Thermal & Storage Outlook

Thermal Energy Day 2025

Aurora provides market leading forecasts & data-driven intelligence for the global energy transition

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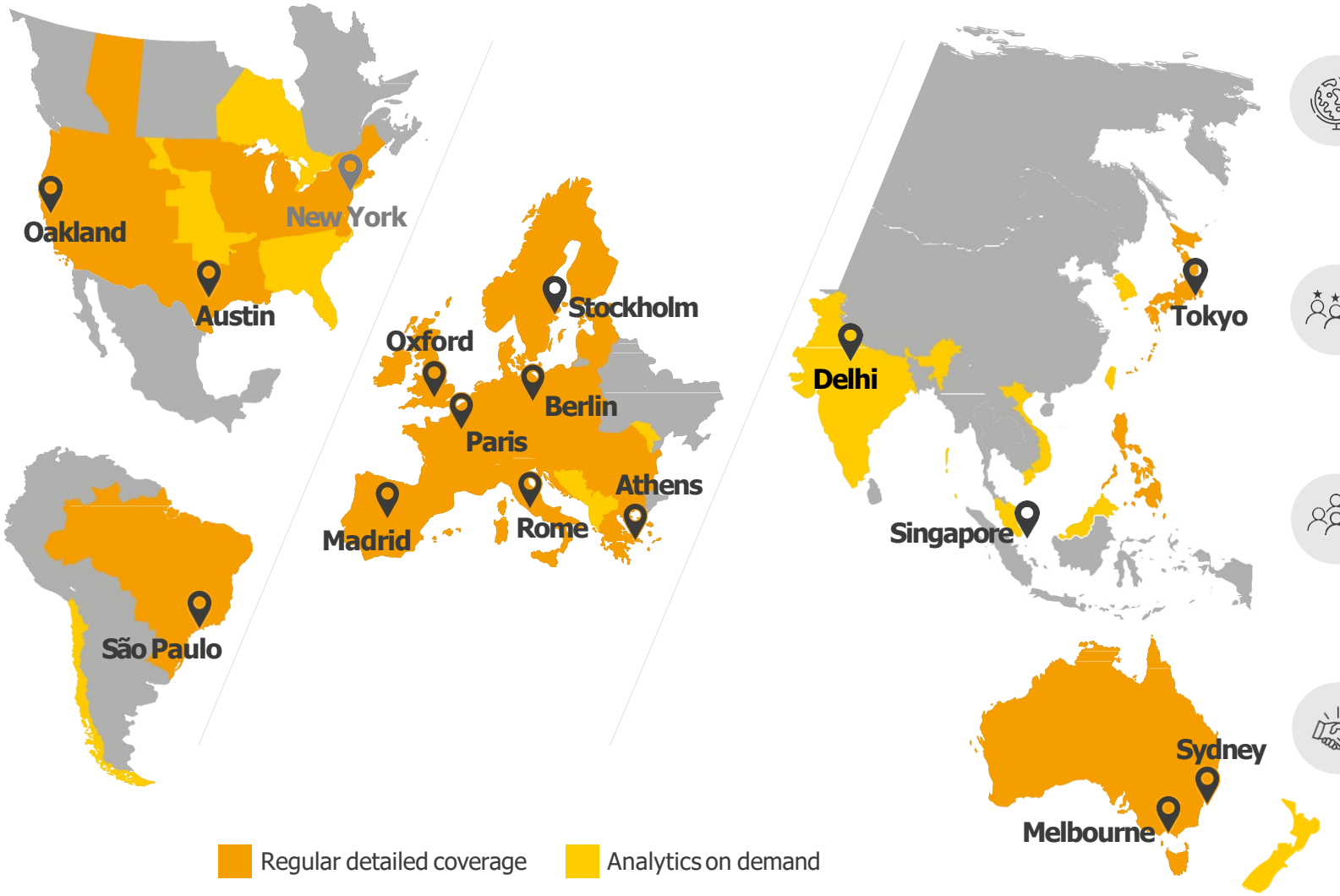
- Power markets
- Renewables & PPAs
- Storage
- Grid & Congestion
- Electric vehicles
- Hydrogen H_2
- Carbon CO_2
- Natural gas



15 offices
and New York coming soon

900
market experts

850+
subscribing companies

150+
transactions supported in 2023

Source: Aurora Energy Research

Our market leading models underpin a comprehensive range of seamlessly integrated services to best suit your needs

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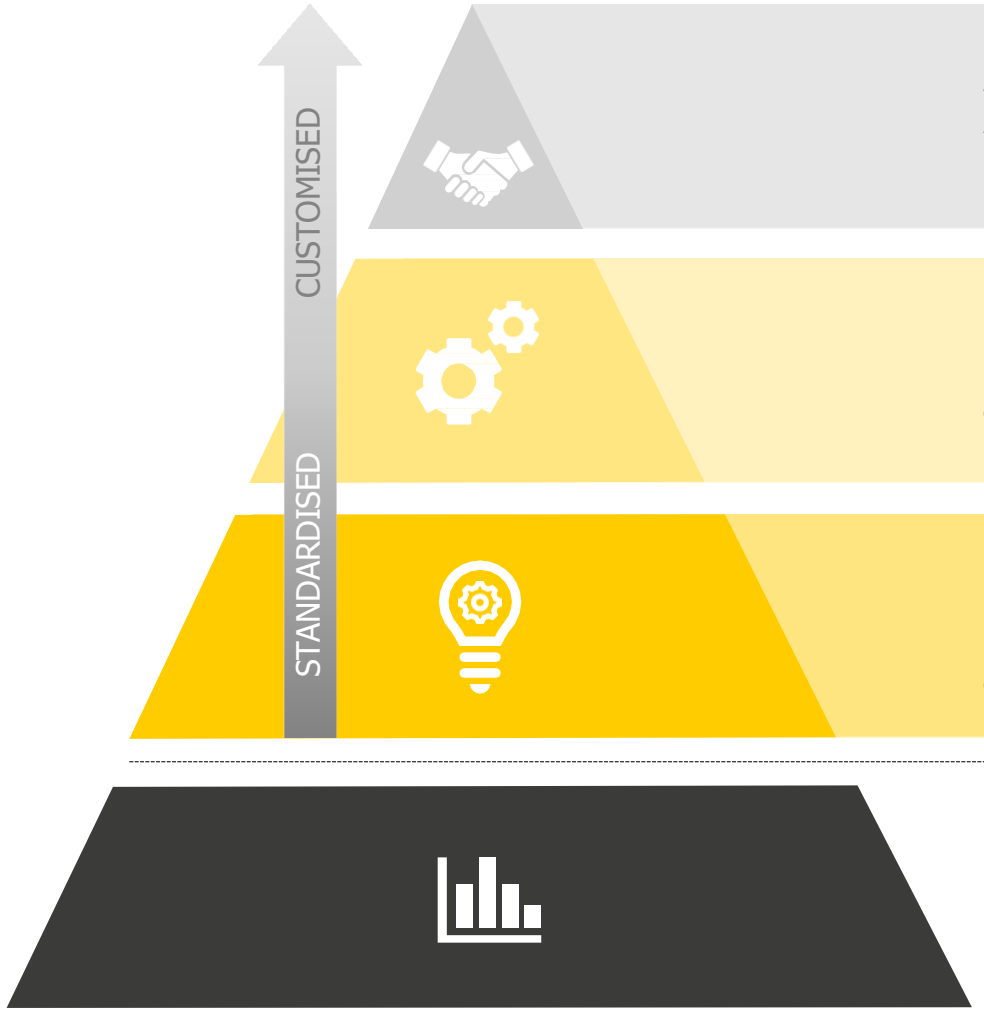

Advisory

Access tailored expert advice and analytics for your crucial projects

Trusted advice and dedicated support for strategy, investments, transactions and policy engagement

1400+ projects globally

Software Solutions

Make standard analysis bespoke through direct access to our models

Unique SaaS subscriptions to create your own scenarios and asset-specific investment cases

150+ company licenses

Subscription Analytics

Receive regularly updated forecasts, sample investment cases and timely deep-dives

Industry-standard outlook reports, bankable price forecasts and strategic insights for power and commodities

750+ subscribing companies

Models & Data

Market-leading models for power, gas, hydrogen, carbon, oil & coal markets

Proprietary and continuously updated cutting-edge models populated with highest quality curated datasets

Developed over 10 years, 40+ dedicated modellers

Source: Aurora Energy Research

Future market prices are fundamentally shaped by commodity prices, the national generation mix and the system demand, including interconnections

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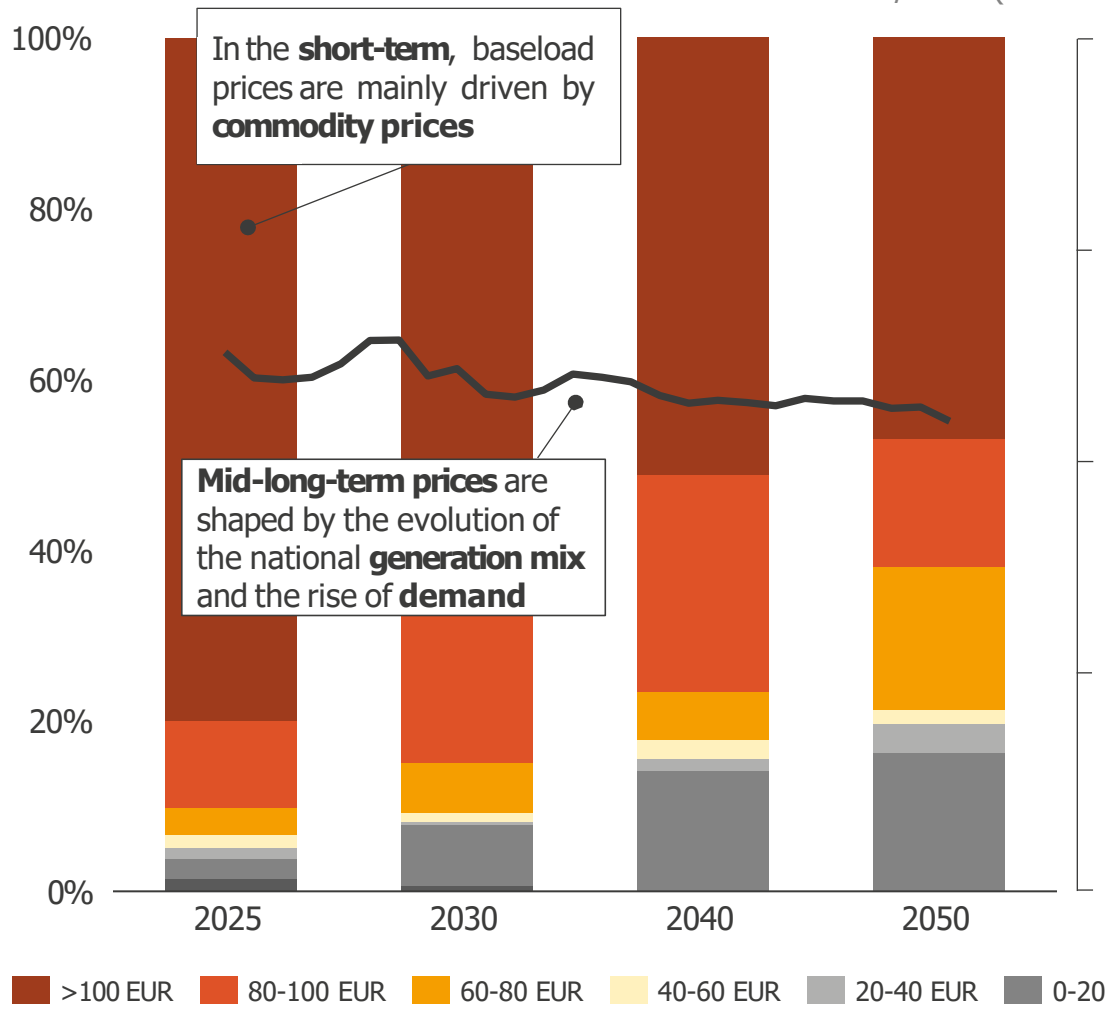
Frequency distribution of electricity prices

%



Baseload price

€/MWh (real 2024)

Main drivers shaping baseload prices

Commodity prices

Gas and carbon prices directly affect the marginal cost of gas CCGT plants, ultimately shaping the trajectory of market prices over the forecasting horizon

Evolution of the generation mix and power demand

decarbonisation of the power generation mix, driven by the **increasing penetration of renewable energy sources**, influences the volatility of market prices

Changes in power demand from industrial, commercial and residential activities and the introduction of **flexible demand** have the potential to impact prices spreads

Cross-border power flows

Imports of cost-effective power can effectively reduce electricity market prices, whereas **power exports** can be considered as a **demand** element for a system, applying upward pressure to market prices

Deep dive in the next slides

1) According to the Aurora Central scenario, published in April 2025.

Sources: Aurora Energy Research

Gas prices rise post 2030 due to increasing Asian demand and limited LNG export buildout; EU ETS prices climb due to stricter emissions targets

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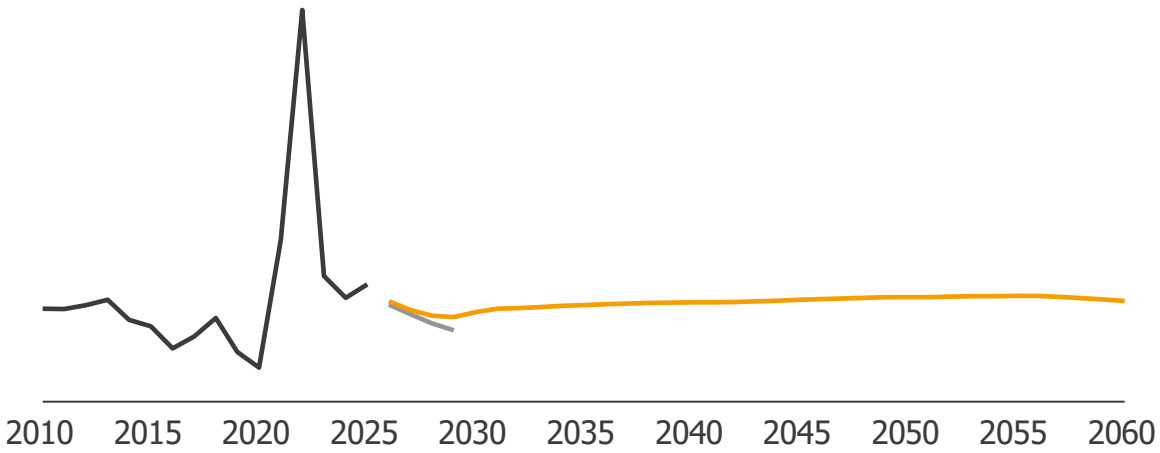
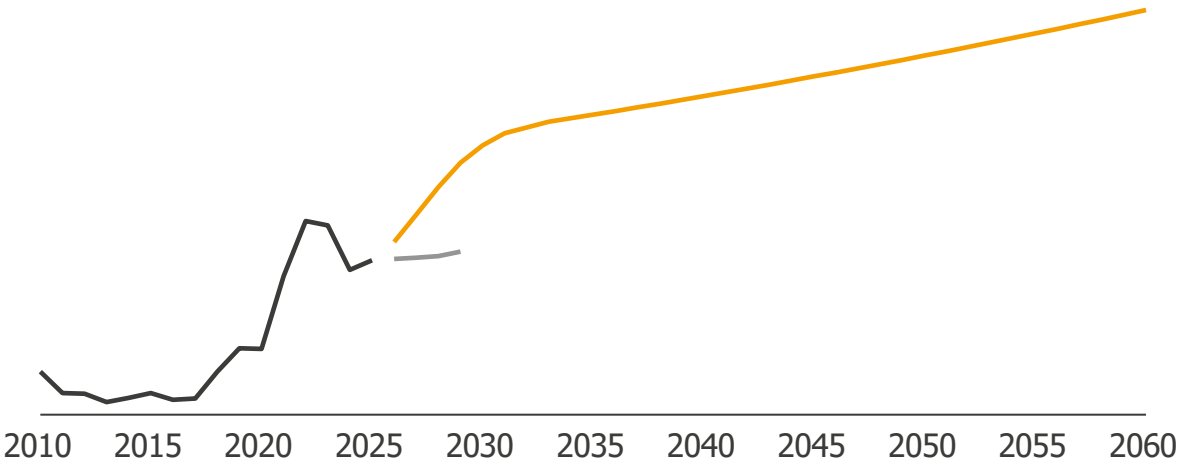
Gas prices
€/MWh (real 2024)[1]



Carbon prices
€/tCO_2 (real 2024)[1]



Short-term (2025-2028)

- Gas prices are expected to average **€31/MWh between 2025-2028**, mainly due to **LNG expansion & subdued European demand**
- Carbon prices average **€90/tCO_2**; EU ETS prices increase in the short term due to **tighter emissions goals**

Mid to long-term (2029-2060)

- Prices gradually rise to **€33.7/MWh by 2060** driven by **lower Europpean industrial output** and **higher Asian demand boost LNG competition**
- Carbon prices rise to **€182/tCO_2 by 2060** driven by **higher industry abatement costs** and **retained policy ambition**

Historical - German gas price | Futures - German gas price[2] | Q4 2025 Central

1) For years 2026-2028, the prices shown consider current futures prices for the years in question, with declining weights. In 2025, forecast prices include historical prices up to Aug-25. 2) Futures on trading days between 04/08/2025 and 29/08/2025. For gas, THE historical and futures prices are shown.
Sources: Aurora Energy Research, EEX, CME

Lignite and coal phase out, to be substituted by RES and gas CCGT generation; the role of interconnections is also important

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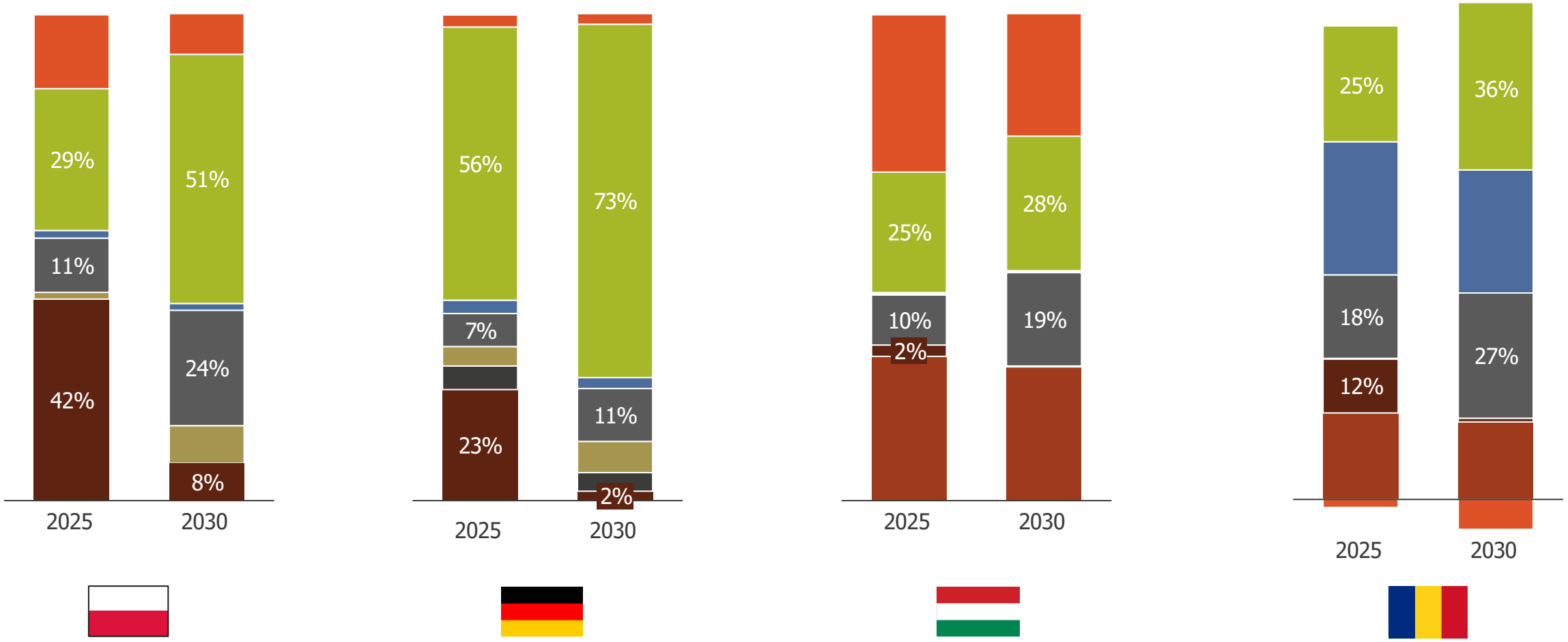
Power generation mix by technology in various European markets (Aurora Central Scenario)

%



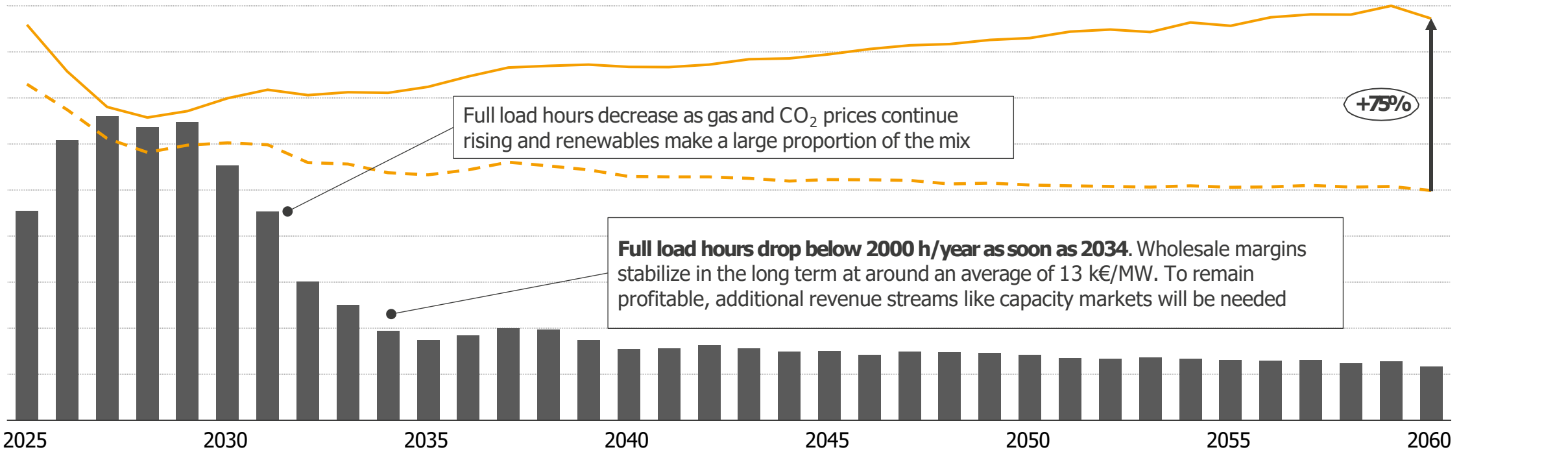
1) Includes solar PV, onshore & offshore wind, as well as CHP units. 2) Other thermal includes waste plants and on-site industrial thermal power plants.

Sources: Aurora Energy Research

Gross margin of a high-merit[1] CCGT peaks at 109 k€/MW in 2027, averaging at around 13 k€/MW from 2040 to 2060

Full load hours
h

Baseload and capture prices
€/MWh (real 2024)



Wholesale gross margin
k€/MW (real 2024)

2025	2030	2035	2040	2045	2050	2055	2060
109	67.2		11.4		13.4		12.1

CCGT full load hours[1] — Baseload price — CCGT capture price[1]

1) CCGT example plant with 55% HHV thermal efficiency.

Source: Aurora Energy Research

Growth of RES in Europe to be accommodated through the addition of more than 40 GW of battery energy storage within the next 5 years

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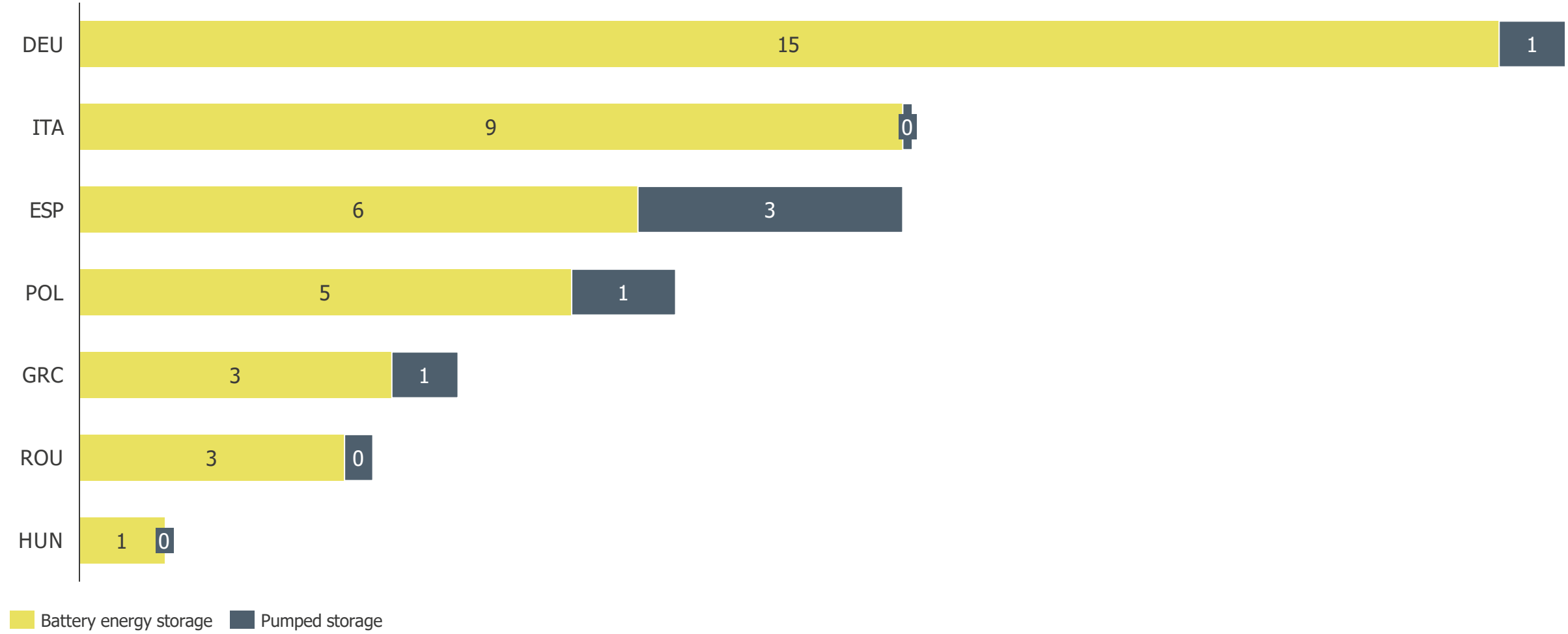
Increase in pumped storage and battery energy storage installed capacity between 2025-2030 (Aurora Central)

GW



Source: Aurora Energy Research

While charging fees make the business case for standalone BESS unviable, co-location could offer a solution to investors

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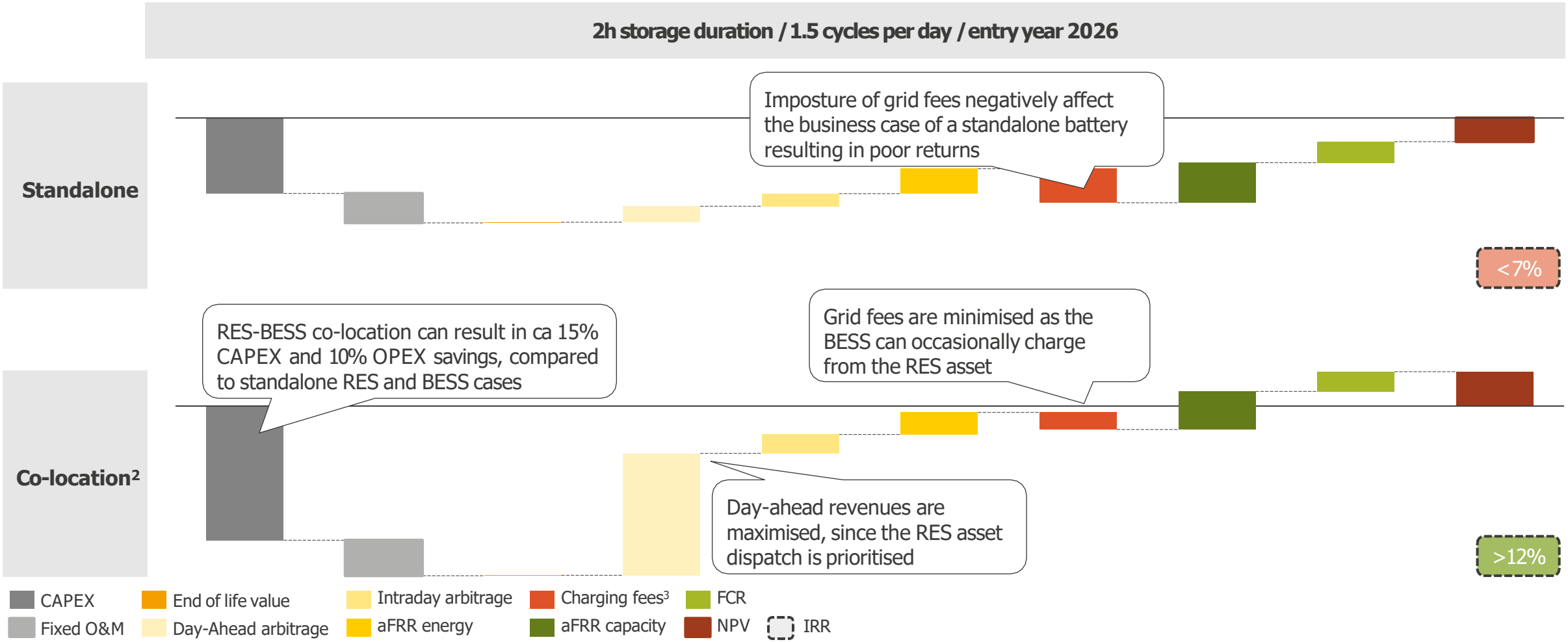
Economics for new-build PV+BESS co-located asset[1, 2]
Net Present Value[1] €/kW (real 2024)



1) Assumed discount rate of 11.5% for all cash flows and a lifetime corresponding to a 63% BESS state of health. 2) DC co-location configuration. 3) Charging fees include no transmission fees until 2026, full variable fees apply 2027 onwards.

Source: Aurora Energy Research

Industrial heat consumption, representing a third of German demand, is dominated by fossil fuels, presenting an opportunity for heat

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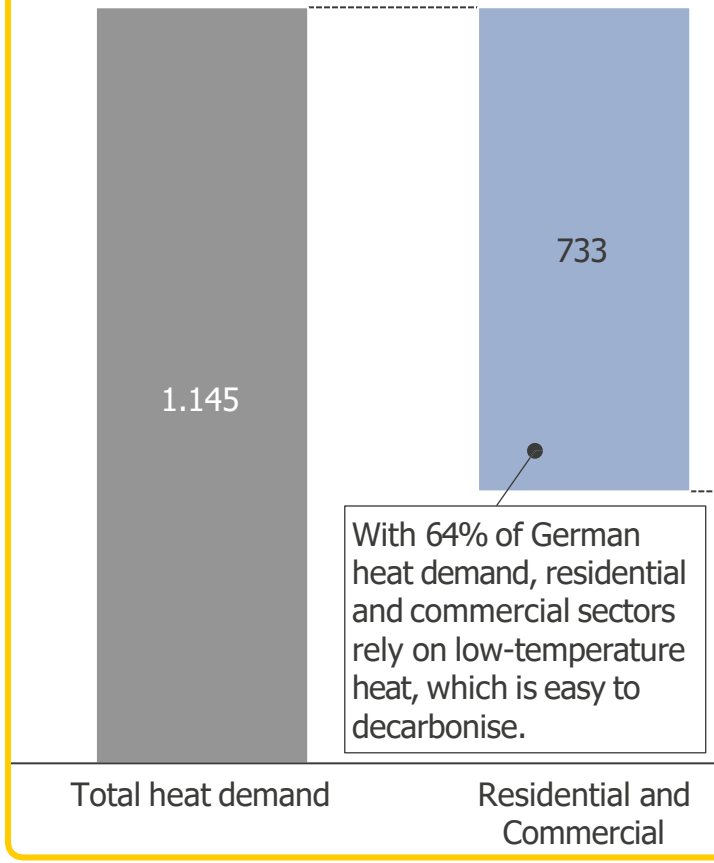
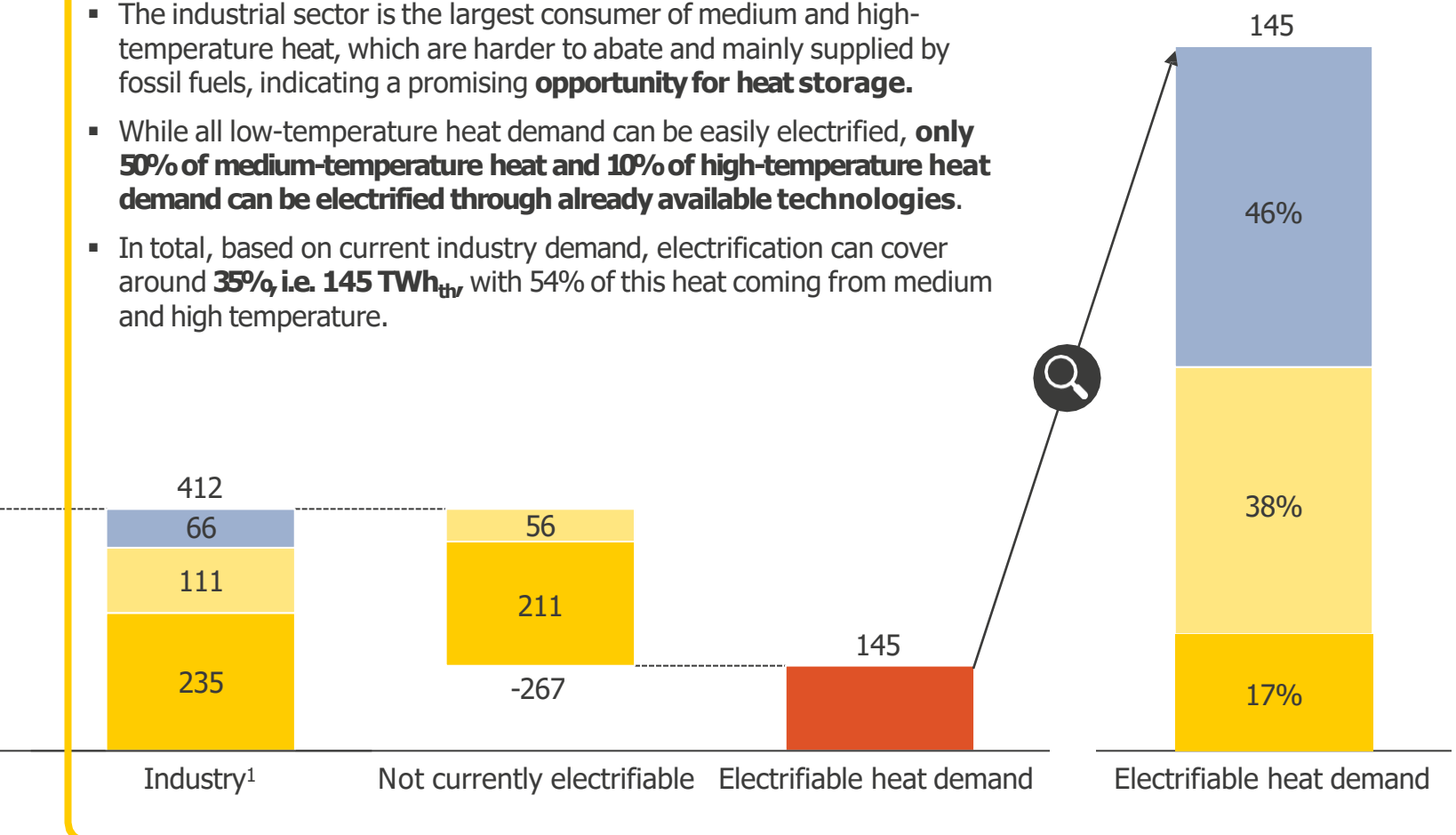
Total heat demand

Breakdown of heat demand in Germany in 2023
%TWh$_{th}$



Industrial heat demand

- The industrial sector is the largest consumer of medium and high-temperature heat, which are harder to abate and mainly supplied by fossil fuels, indicating a promising **opportunity for heat storage.**
- While all low-temperature heat demand can be easily electrified, **only 50% of medium-temperature heat and 10% of high-temperature heat demand can be electrified through already available technologies**.
- In total, based on current industry demand, electrification can cover around **35%, i.e. 145 TWh$_{th}$,** with 54% of this heat coming from medium and high temperature.



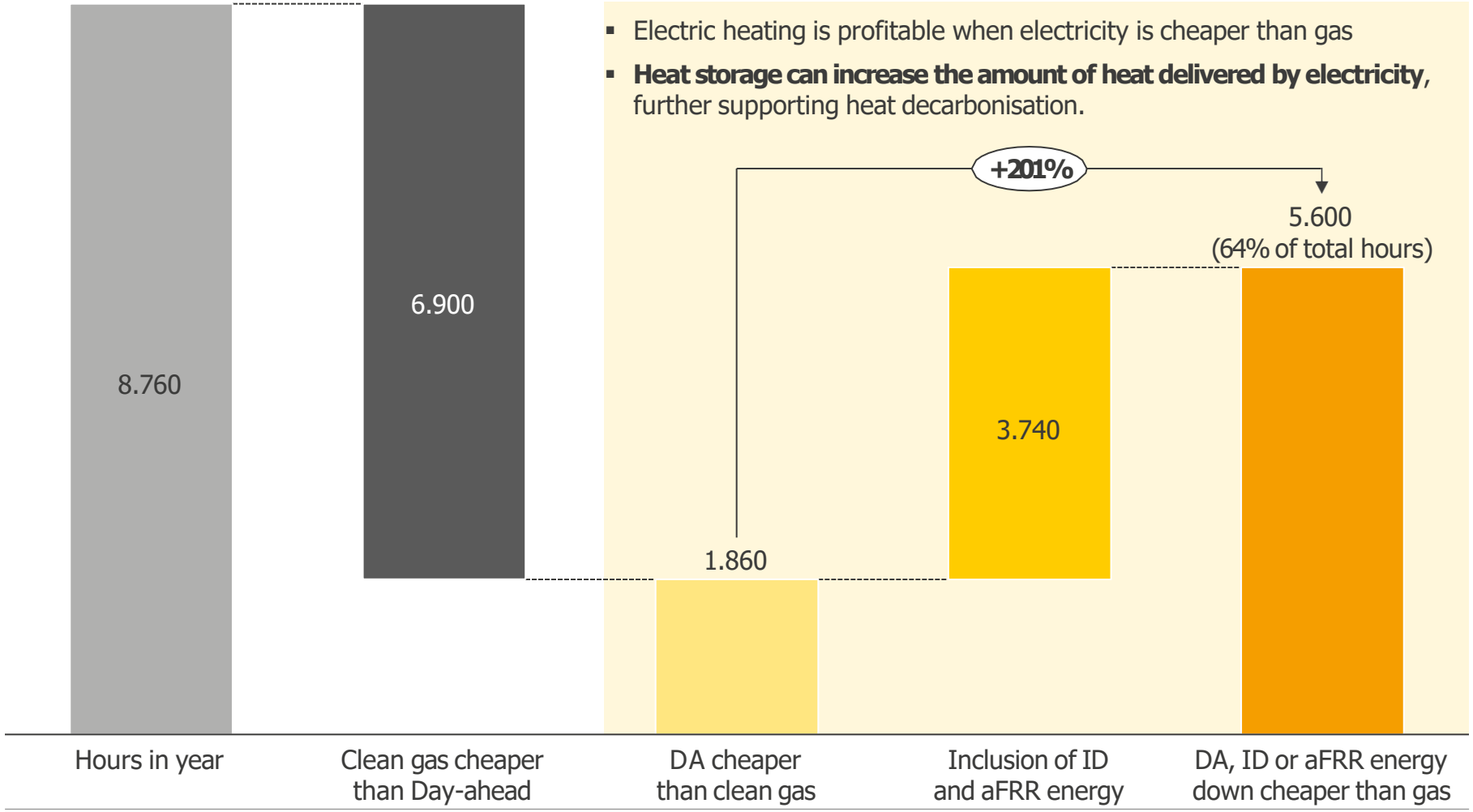
Low temperature Medium temperature High temperature

1) Temperature breakdown estimated based on Fraunhofer study Langfristszenarien 3, 2019.

Sources: AG-Energiebilanzen, Fraunhofer ISI

For 2025, electricity is projected to be cheaper than clean gas during 64% of hours, when using DA, ID and aFRR energy down

Comparison of profitable hours for heat production between clean gas[1] and electricity in 2025
Number of hours



- Electric heating is profitable when electricity is cheaper than gas
- **Heat storage can increase the amount of heat delivered by electricity**, further supporting heat decarbonisation.

1) The price of clean gas is defined as the sum of natural gas price and the ETS price for the carbon content of gas

Source: Aurora Energy Research

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Comments

- **Assuming the electrification potential of the industry sector of 145 TWh_{th}** (2023) stays constant and considering the market conditions (electricity v. gas prices + ETS), we would expect around **73 TWh_{th}** of heat covered by electricity sources.
- This is only possible when optimizing the electricity feed-in from DA, ID and aFRR energy.
- When charging only from from the Day-ahead, electricity is cheaper only in 21% of hours.


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McKinsey & Company

Energy Infrastructure for the Net-Zero Era

Flexibility merit-curve

October 10th, 2025

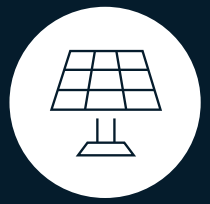
Your speaker

Godart van Gendt

Partner

Amsterdam

Key messages



Large infrastructure need ahead

~USD 23 trillion investment in the energy sector, with significant funds flowing into storage, renewables, and grid expansion

Managing renewable oversupply will become the day-to-day reality

Rapid RES growth results in oversupply and undersupply, driving increased power price volatility

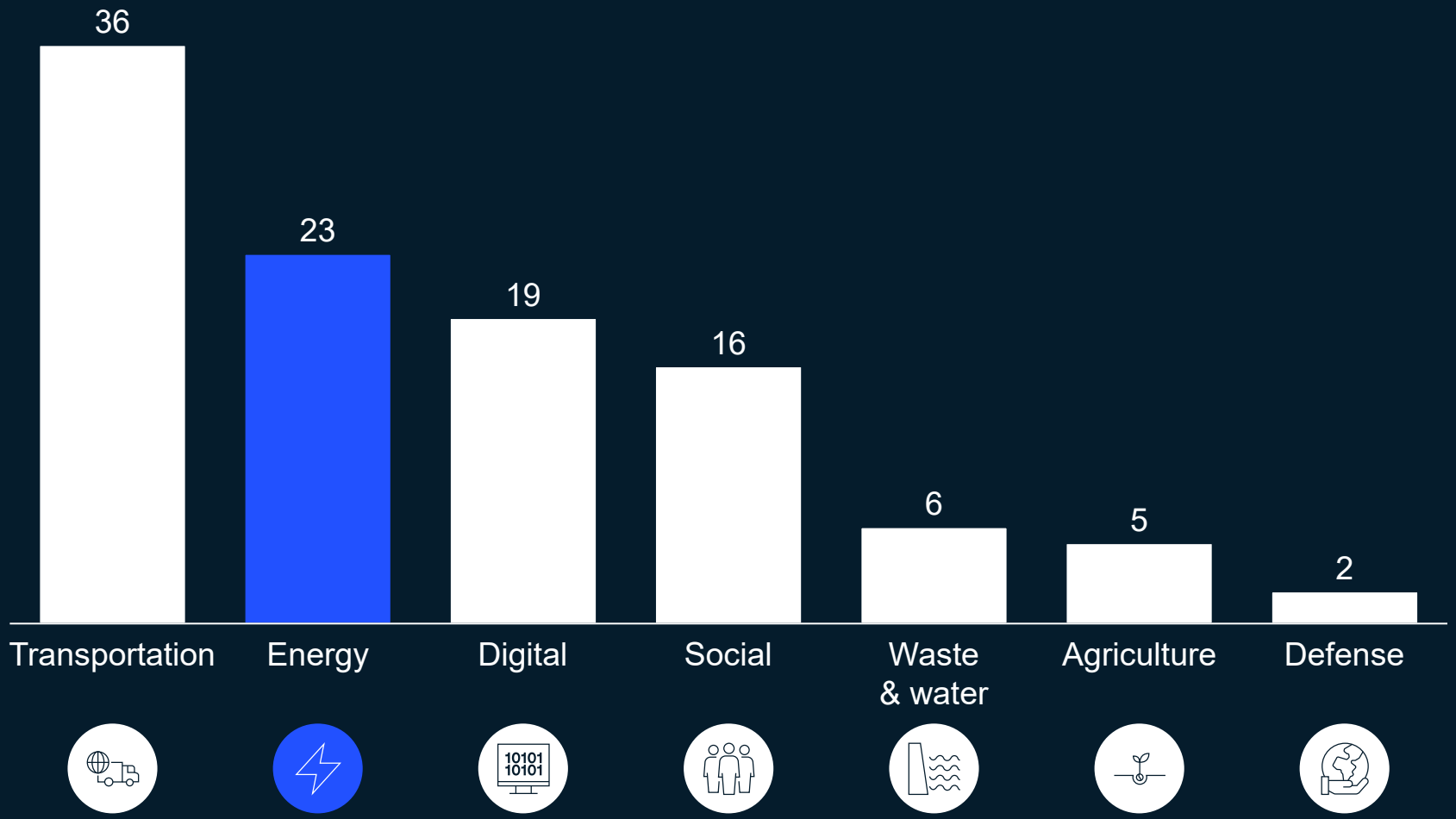
Focus

Business case for heat flexibility is compelling

The financial attractiveness of flexibility varies by technology. Electrified heat is one of the best options

Infrastructure is a $106T opportunity over ~15 years, with energy the second-largest infrastructure area

Cumulative infrastructure investment projected through 2040, USD tn



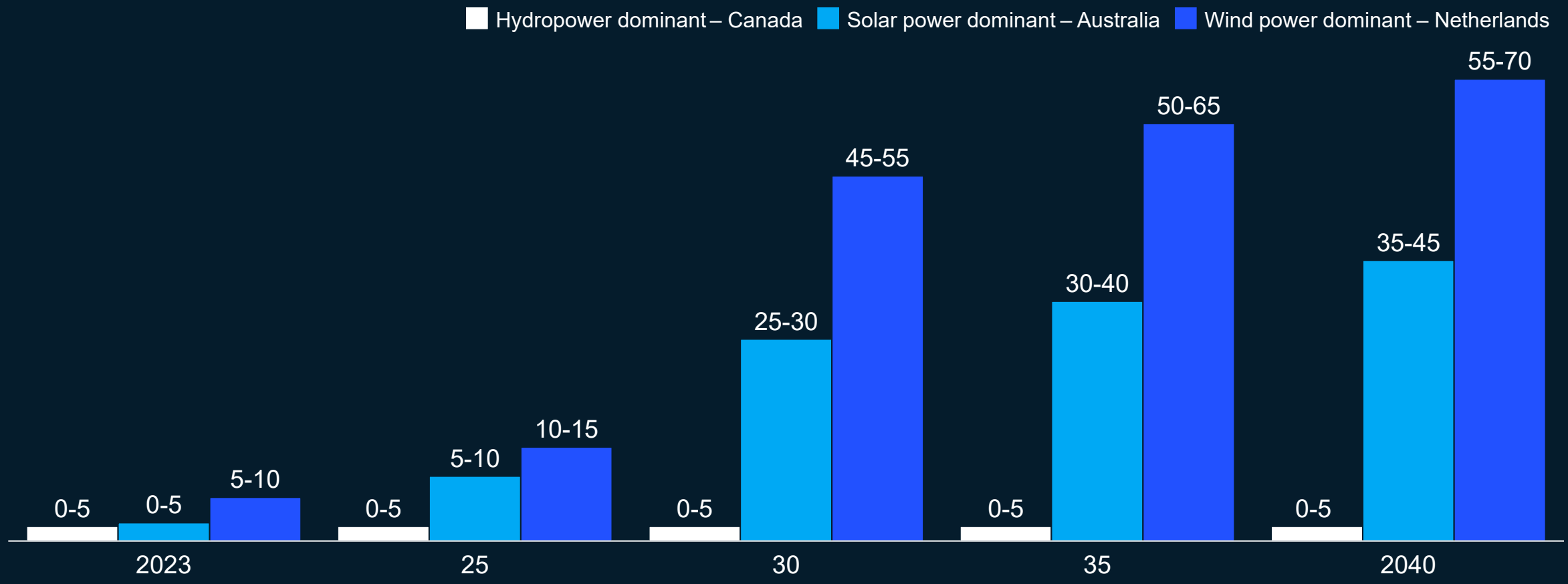
Check our latest report for more details on the future of infrastructure

Power systems across the globe will see growing occurrence of oversupply with increasing penetration of variable renewables

Comparison of different power systems for oversupply occurrence

Indicative

Time when variable renewables provide > base power demand, %



Source: McKinsey energy solutions, Canada Energy Regulator, AEMO

Flexibility will play a significant role, matching variable renewable supply to meet demand

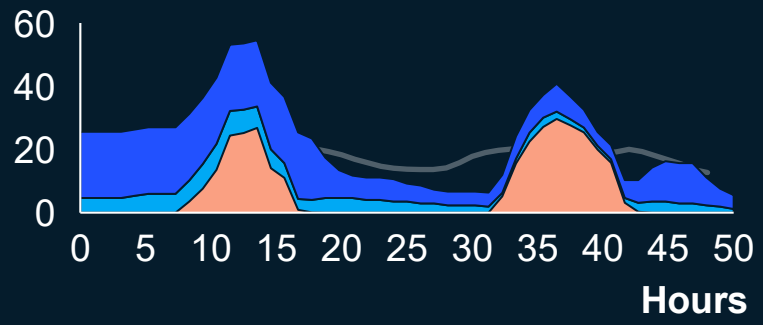
Future energy systems

Illustrative

Solar Onshore wind Offshore wind Demand

Supply

Load, GW



Wind

Solar

Flexibility

Battery

Long Duration Energy Storage

Thermal Energy Storage

Hydrogen based options

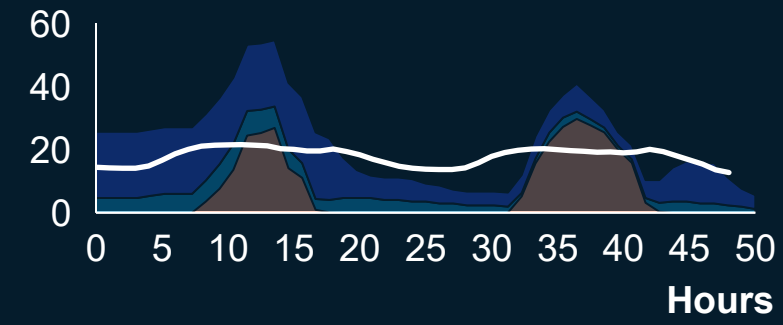
Demand based options, e.g., EV charging

Infrastructure

Fossil-fuel storage

Demand

Load, GW



Industry

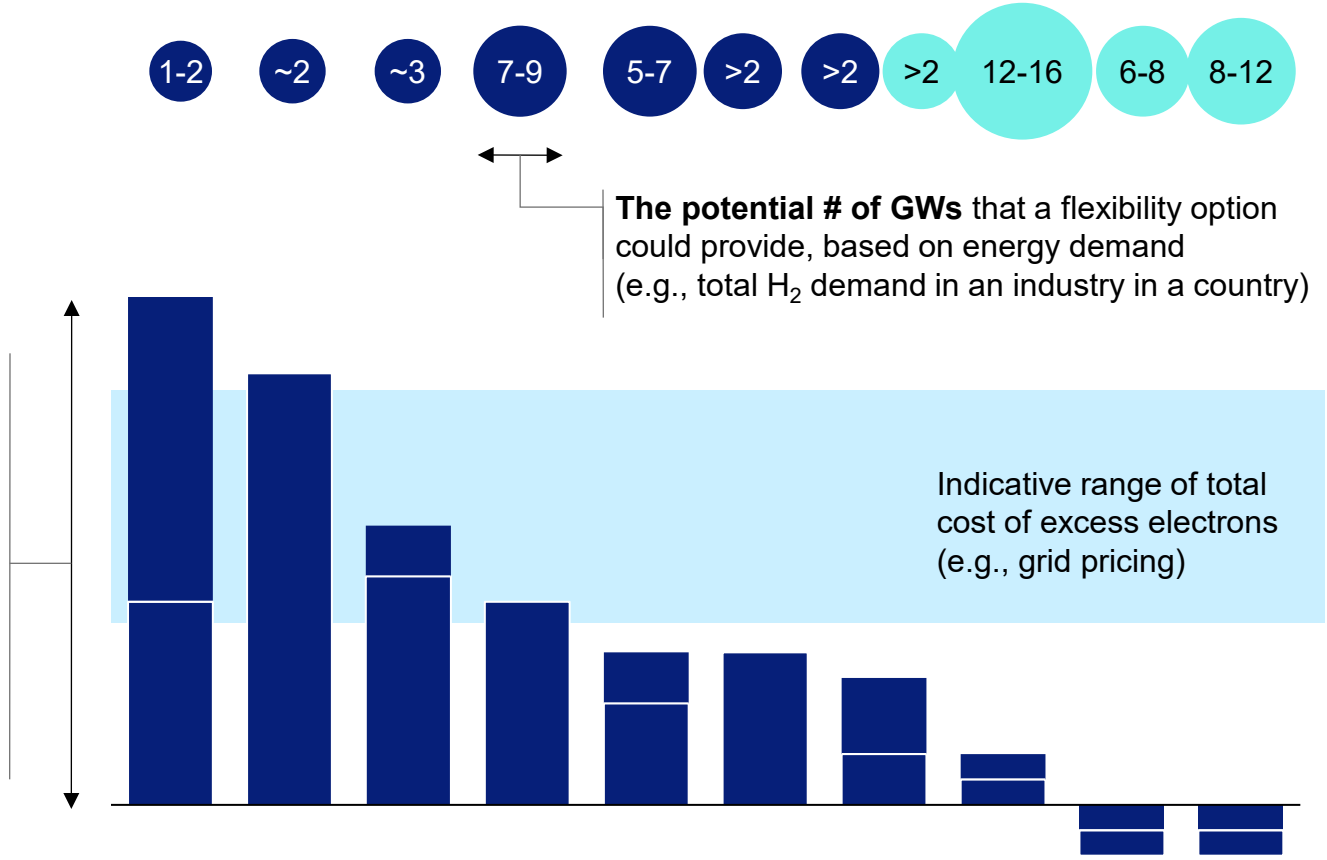
Transport

Buildings

The flexibility cost curve compares potential flexibility options

Illustrative

Value of otherwise curtailed electrons in 2030 – Cost perspective, EUR/MWh

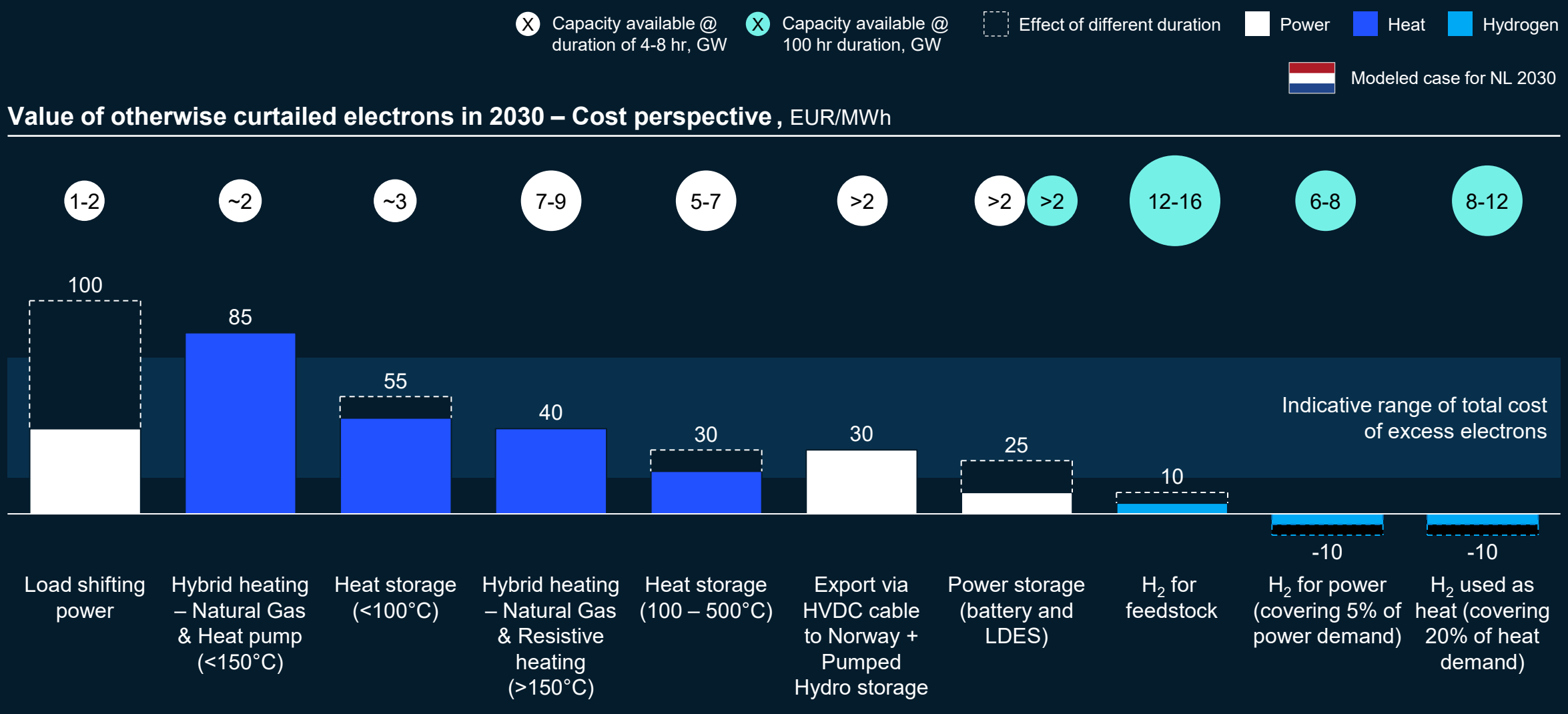


How to consider the options

The options are not exclusive, e.g., heat demand could both be fulfilled by H_2 or electric boilers

The potential # of GWs is based on demand outlook for an option, regardless of supply

The economic attractiveness of flexibility options varies across heat, power & hydrogen

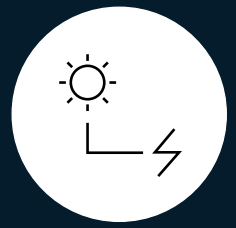


Source: McKinsey Energy Solutions, ENTSOE

How to ensure a successful implementation of flexibility?

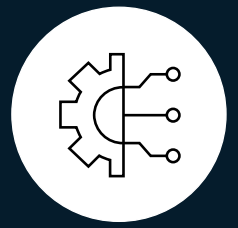
Target right use cases

Target use cases / geographies with **strong fundamentals** (price volatility, low grid charges)



Maximize on-site flexibility

Change and adapt the **site setup** (e.g., hybrid electrification with direct wire renewables). Read more here.



Reform grid

Adopt best practices on **smart grid pricing** and deploy them across Europe

Partner with the right parties

Create the right partnerships that can help you deliver on all the elements of the value chain

THERMAL ENERGY DAY

Budapest, 8 October 2025

Session 2

Matching System Demands with Industrial Realities

System-friendly Electrification of Industry

Speakers:

Zsuzsanna Pato Power Team Lead, Principal at Regulatory Assistance Project (RAP)

RAP
REGULATORY ASSISTANCE PROJECT

8 Oct 2025

System-friendly electrification of industry

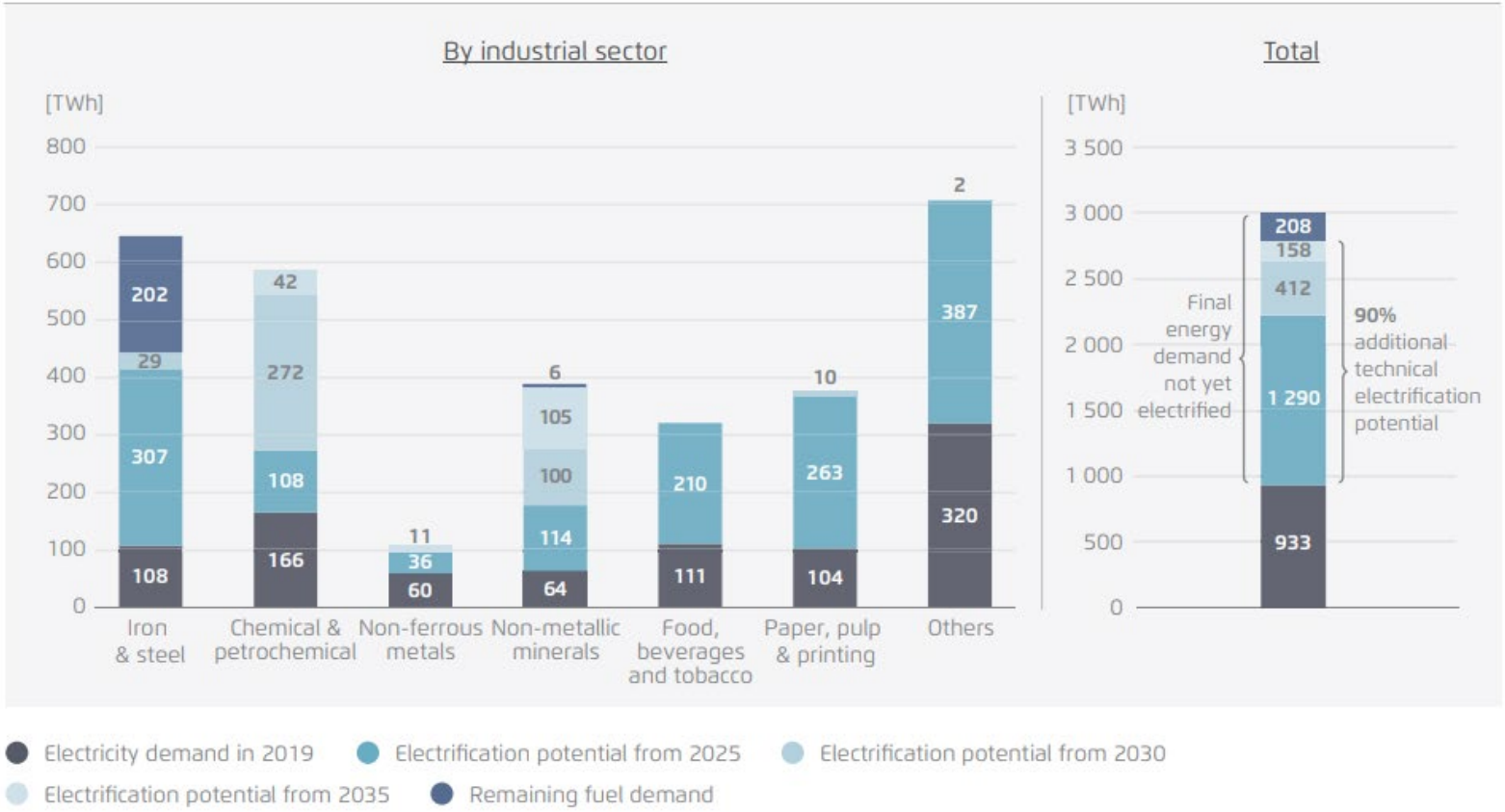
Thermal Energy Day

Zsuzsanna Pató
zpato@raponline.org
RAP

Electrifying industry has many social benefits

- Decarbonisation ≈ equivalent to 50% of all European buildings heat demand
- Electrification = energy efficiency
- Getting off gas – security of supply and price volatility
- Industrial modernisation for a competitive national/European economy
- Closing down the gas grids

Electrification potential is large



Source: Fraunhofer ISI. (2024). Direct Electrification of Industrial Process Heat: An Assessment of Technologies, Potentials and Future Prospects for the EU

System impacts

Additional pressure → **Flexibility** → **Lower system cost**

- More power plants
- More power grids
- The S=D challenge

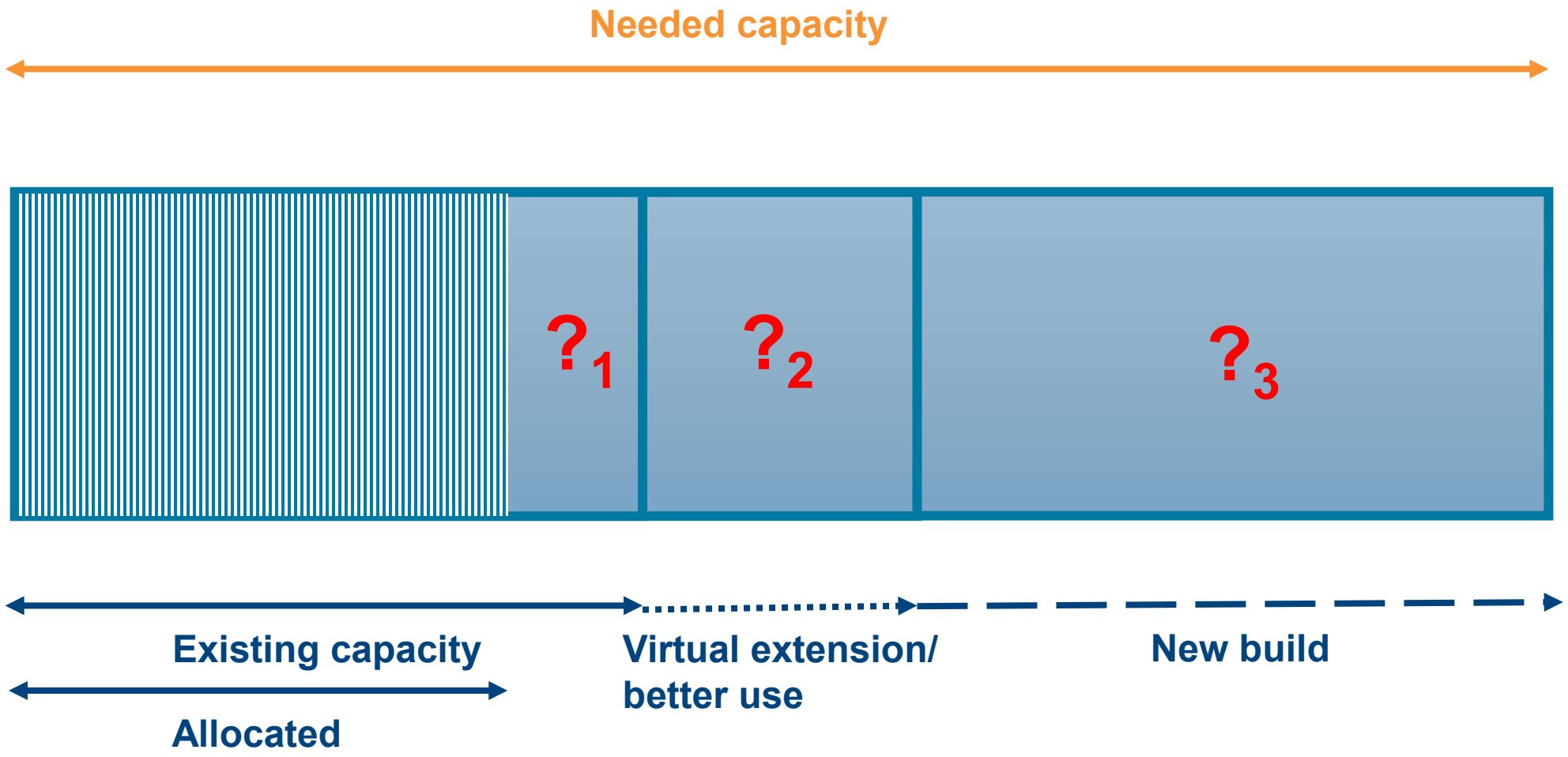
- Direct demand response
- Storage: heat and electric
- Co-location

- Less RES curtailment
- Lower wholesale prices
- Less grid congestion

How to mobilise flexibility?

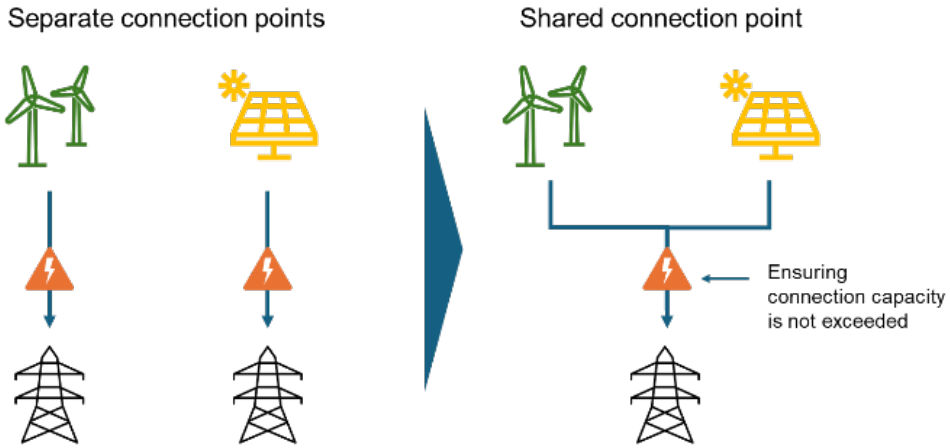
	Markets	Grid
Price	Wholesale price	Network tariff
Access	Balance, flexibility	FCAs

How can you enhance grid capacity?



?$_2$:Utilization of existing grid capacities

Allow colocation/pooling

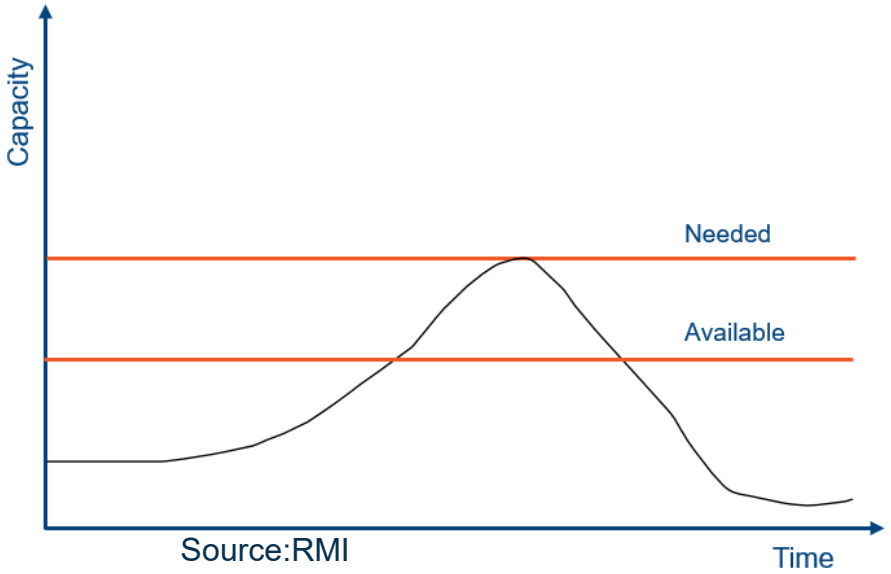


Source:RMI

?$_2$:Utilization of existing grid capacities

Allow colocation/pooling

Allow flexible connections



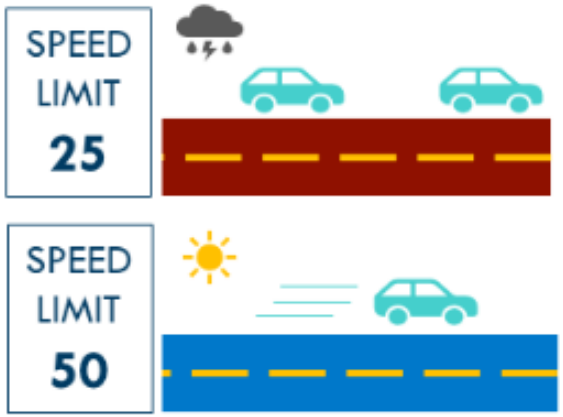
?$_2$:Utilization of existing grid capacities

Allow colocation/pooling

Allow flexible connections

Incentivise DSOs/TSOs to:

- **Use grid enhacing technologies**



Source:RMI

$?_2$:Utilization of existing grid capacities

Allow colocation/pooling

Allow flexible connections

Incentivise DSOs/TSOs to:

- **Use grid enhacing technologies**
- **Procure flexibility**

Source:RMI

?$_2$:Utilization of existing grid capacities

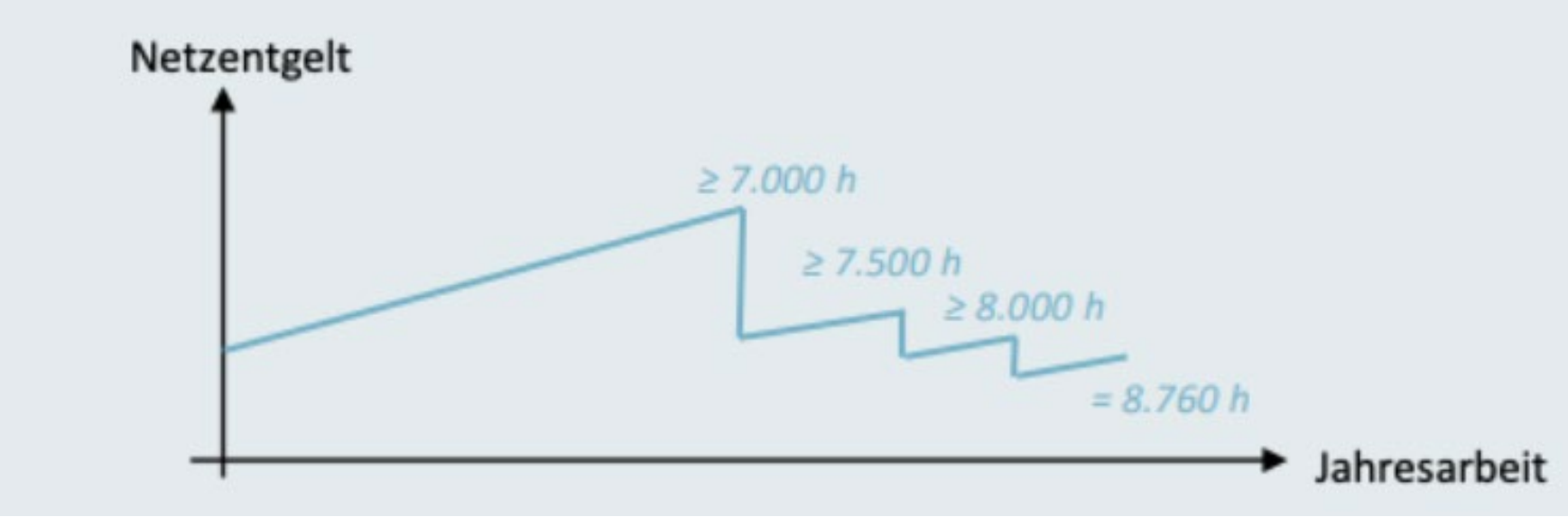
Allow colocation/pooling

Allow flexible connections

Incentivise DSOs/TSOs to:

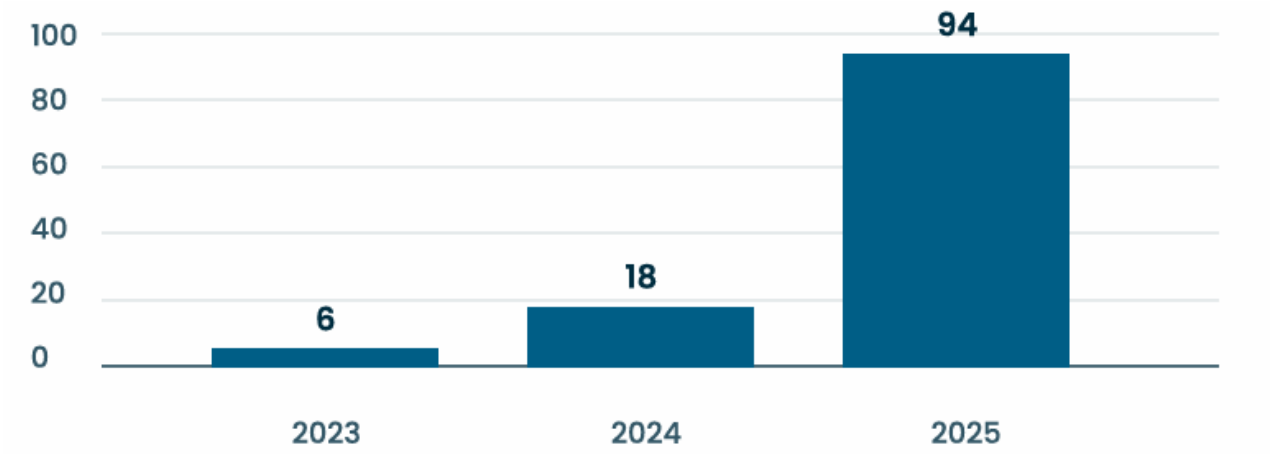
- **Use grid enhacing technologies**
- **Procure flexibility**
- **Provide price signals for grid users**

Bad incentives: The 7000-hour rule in Germany



Source: Agora/RAP/FIM (2025): Industrielle Energie flexibilität ermöglichen

FCAs in the NL contracted with load



Types:

19 ‚residual' (*Reststroom*) - DSO/TSO

73 ‚ToU' (*Blokstroom*) - DSO

2 ‚time limited grid use right' (*Tijdsduurgebonden transportrecht)* - TSO

Plans:

Scaling up

How to convince anyone giving up firm rights?

Source:Aanpak netcongestie | Tweede Kamer der Staten-Generaal

Source: Netbeheer Nederland (2025). Stand van de Uitvoering De voortdurende beweging op het gebied van elektriciteit

Resources

- https://www.raponline.org/toolkit/rip-first-come-first-served/
- https://www.raponline.org/knowledge-center/flexing-industrial-muscle-electrifying-process-heat-with-electro-thermal-energy-storage/
- https://www.raponline.org/toolkit/transparent-grids-for-all/

About RAP

Regulatory Assistance Project (RAP)® is an independent, global NGO advancing policy innovation and thought leadership within the energy community.

Learn more about our work at raponline.org

zpato@raponline.org

System Needs: TSO Pespective

Márton Gábor Kádár

Head of Balancing services development

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MAVIR 25

System needs – TSO perspective

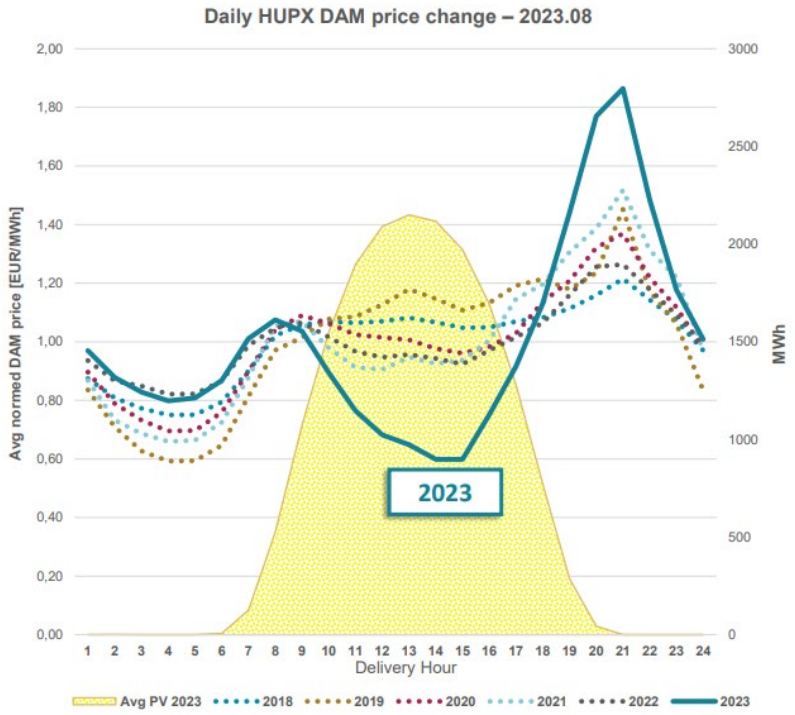
Thermal Energy Day 2025

8th October 2025

| SYSTEM SHIFT: FLEXIBILITY NEEDS BOOMING

Hungarian system volatility evolved with high PV and high imports...

Duck curve is an everyday reality since 2023 / 2024, next steps should follow...

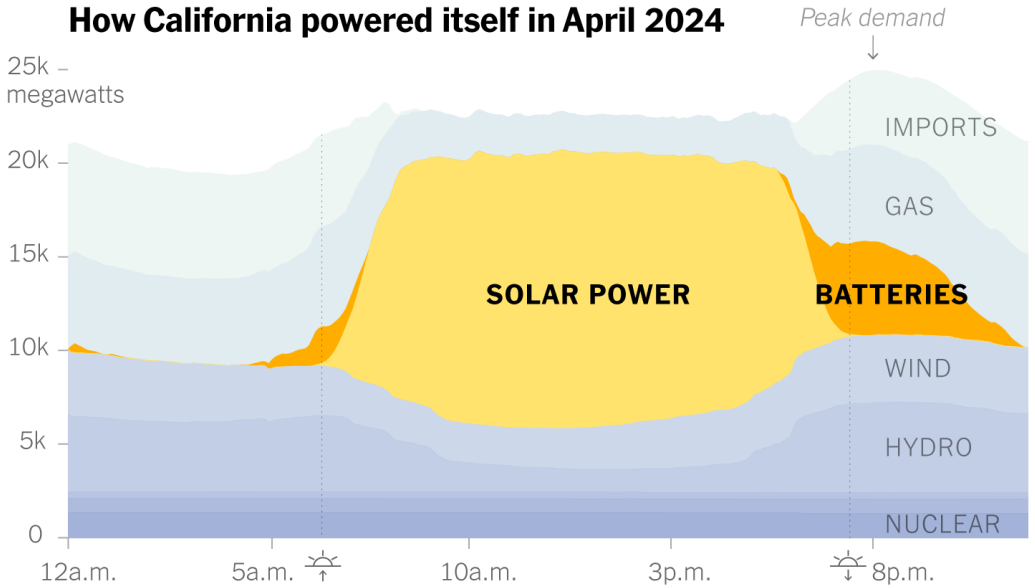


Source: HUPX presentation

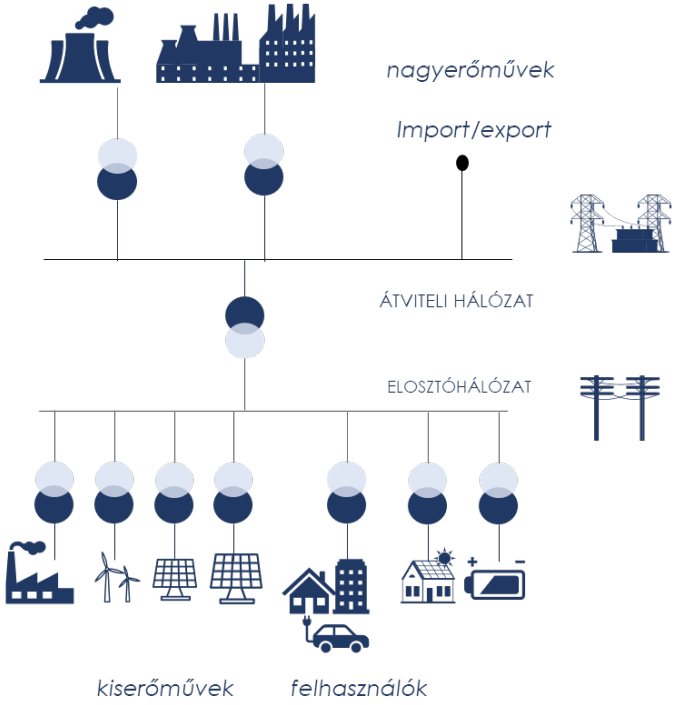
...storage needs to be the next step for the flexibility challenges.

Next step should be a California-like integration of storage.

Battery capacities are being built but we will also need an evolved industrial consumer sector.



BEYOND FREQUENCY: EMERGING COMPLEXITY FOR SYSTEM OPERATORS



Complexity

With thousands of distributed assets — from industrial heat pumps to electric vehicles — **system operation is becoming far more complex.**

Perfected balancing

Frequency restoration – balancing – processes and markets are being perfected each day close to real time however, the story does not end here…

Beyond frequency

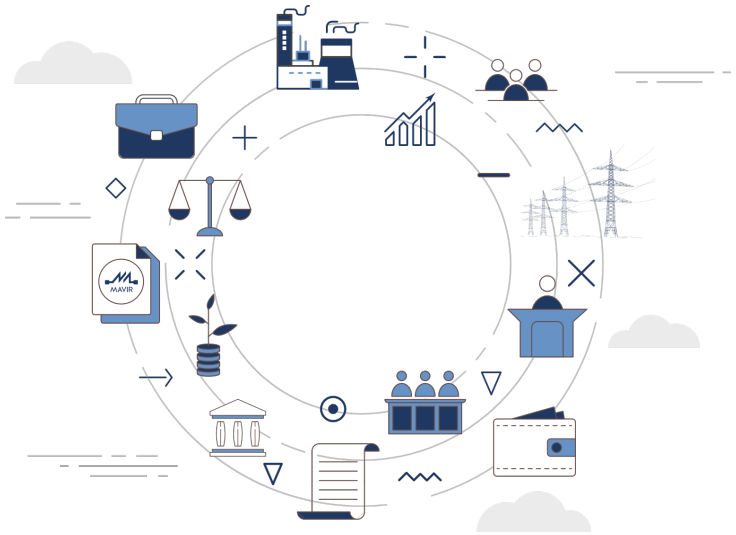
We're moving beyond frequency control into a world where voltage management and congestion handling are becoming daily operational challenges, at every voltage level.

Coordination is key

This requires much stronger coordination and more critical intraday processes, both technically and operationally between not only system operators.

| SMARTER COORDINATION

To make this work, we need **awareness, tech-powered operation and faster, more critical processes on all sides** of the system.



Multi-service flex

We are asking the market not just for megawatts of capacity, but for **automated, digital, multi-service flexibility** — available in real time.

Enablers and cooperation

That means **tighter cooperation not only between TSOs and DSOs, but also among aggregators, flexibility providers, and industrial users.**

Enablers like data sharing, automation, **interoperability, market frameworks** all are necessary.

Technologies

Everyone and **all types of technologies in the energy chain should become aware and an active system participant** in a feasible way.

MAVIR
/ Powered by MVM

MAVIR 25

Thank you for your attention!

THERMAL ENERGY DAY
Budapest, 8 October 2025

Thermal Energy Across Sectors: Decarbonizing the Industrial Base

Antoine Koen

Cleantech Analysts at Future Cleantech Architects

FCA Future Cleantech Architects

Thermal Energy Across Sectors: Decarbonizing the Industrial Base

Dr Antoine Koen

Thermal Energy Day

Budapest, 8 October 2025

FCA Future Cleantech Architects

What we do

Our mission:

Closing the toughest innovation gaps in hard-to-abate sectors.

Our principles:

- Non-profit.
- Independent.
- Science-based.

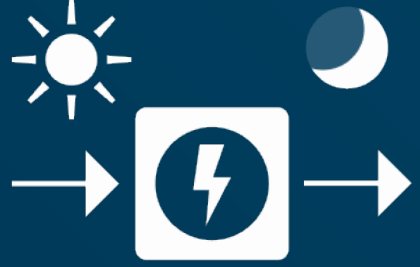
We cover neglected and lagging sectors

Construction

Aviation

Industrial heat

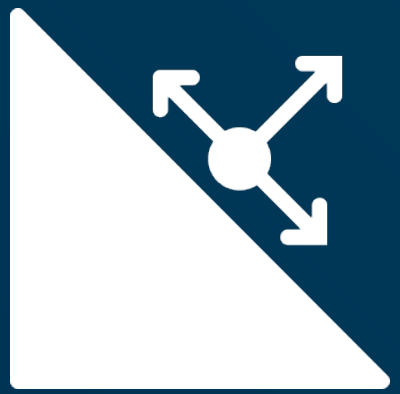
Hydrogen



Energy storage

We drive cleantech from research to public policy design

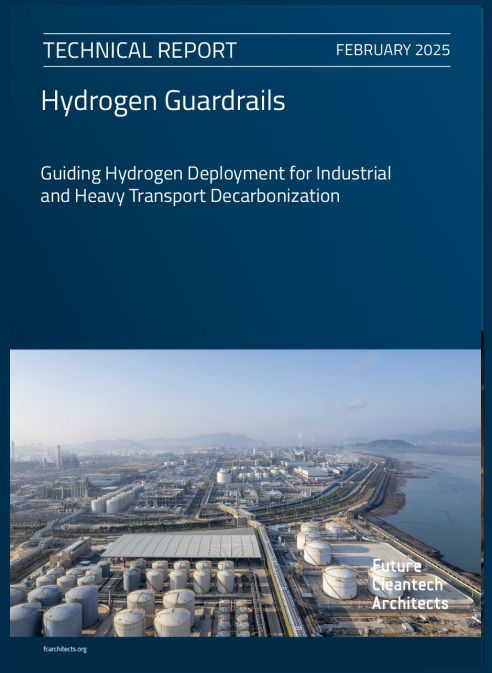
Research &
Development



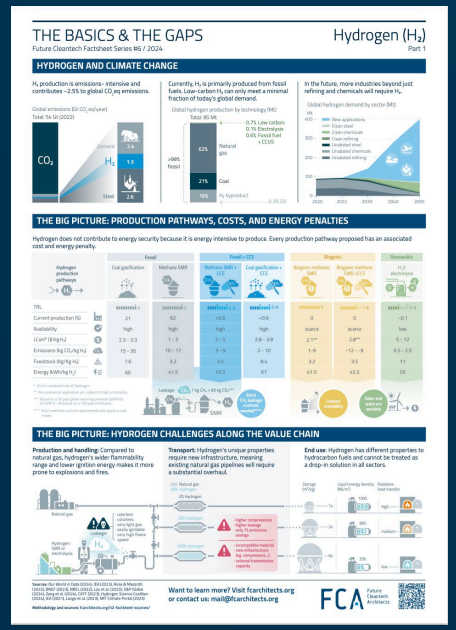
Acceleration through
Valley(s) of Death

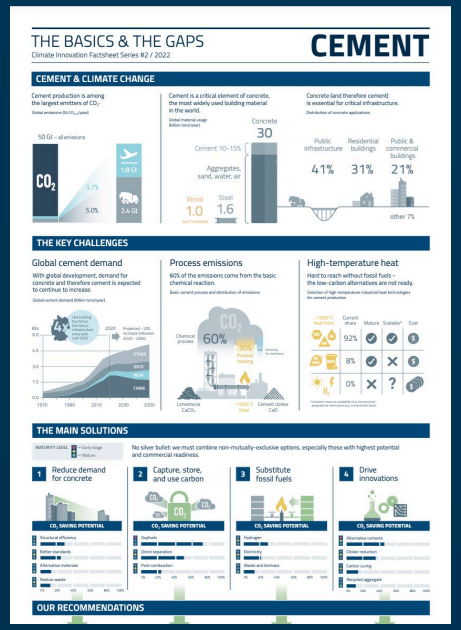
Advocacy &
Policy Work

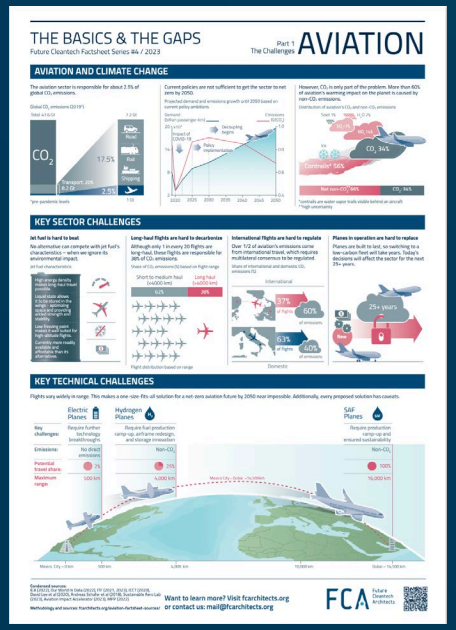
Reports: Science-based technical reports and policy briefs

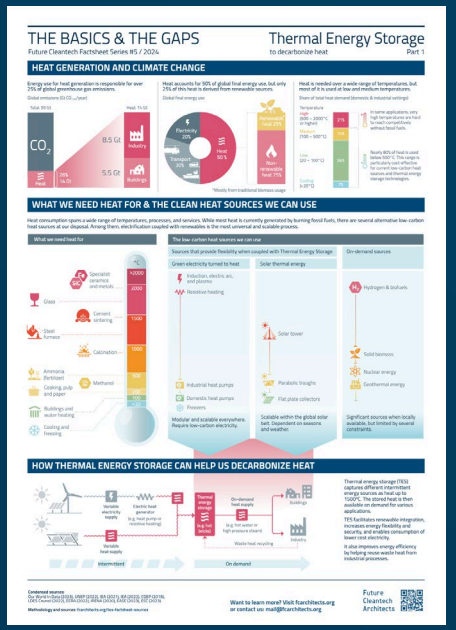


Factsheets: Our work summarized









Hydrogen

Cement

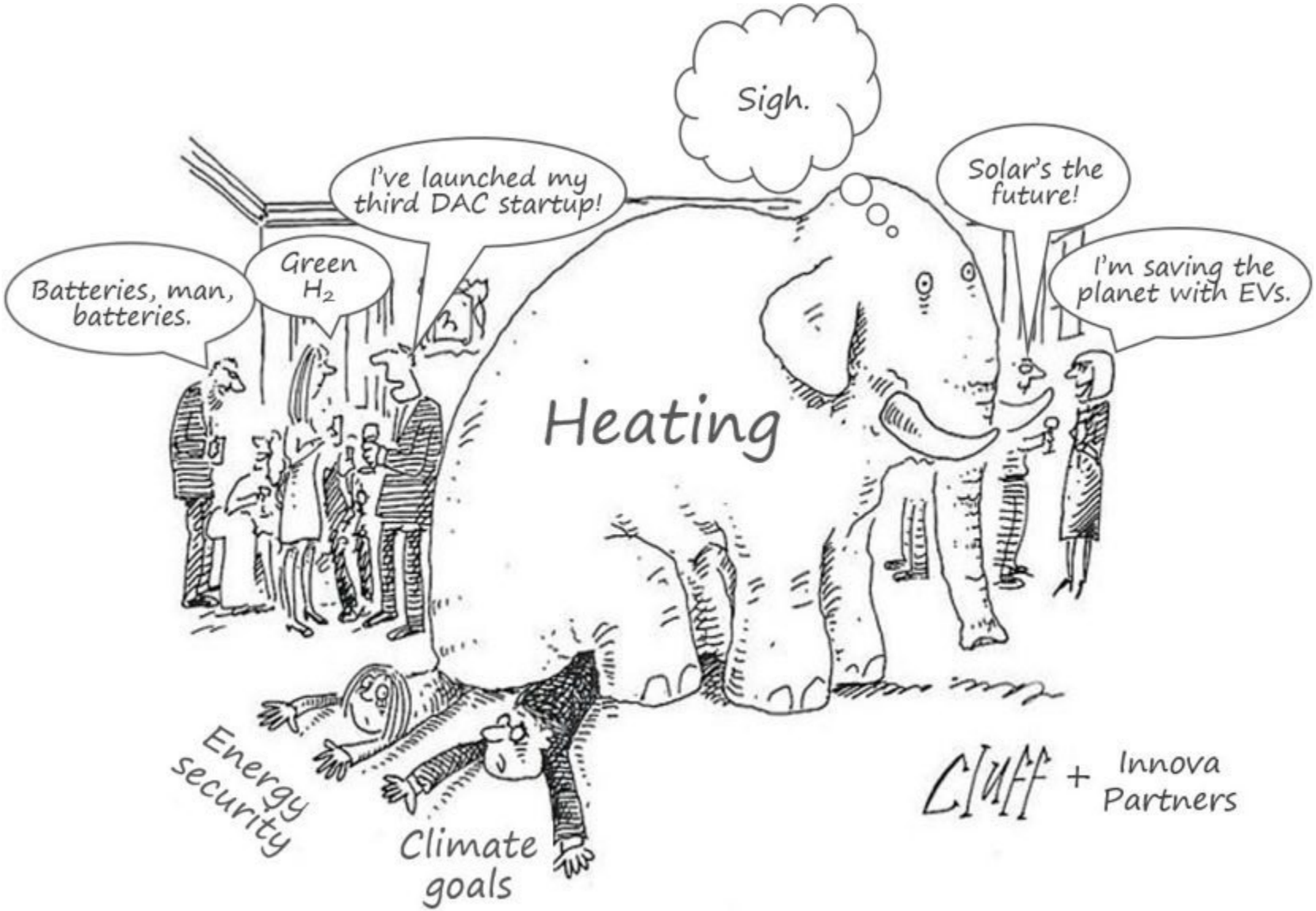
Long Duration Energy Storage

Aviation

Thermal Energy Storage

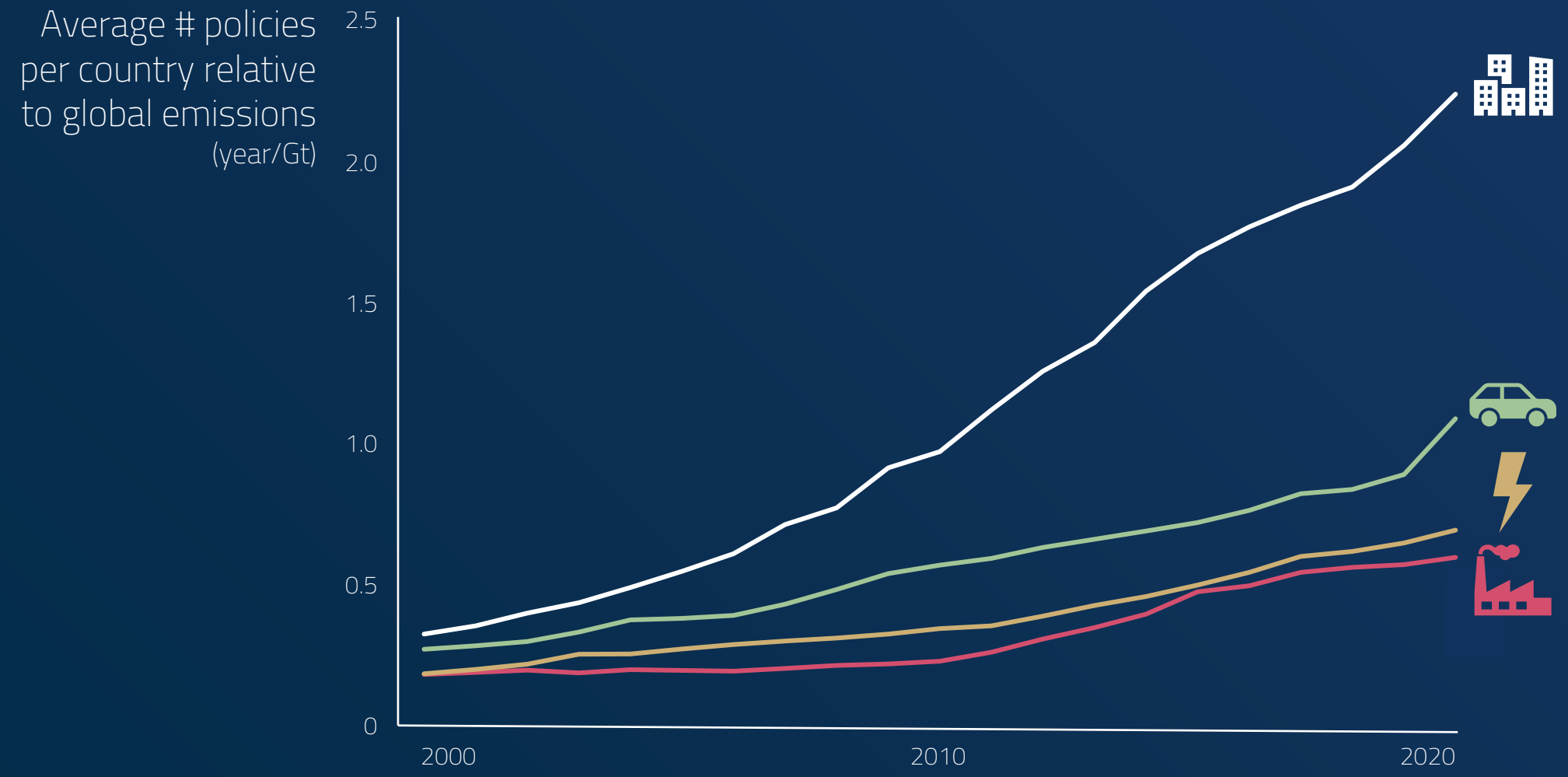
Why care about thermal energy?

Photo: J. Wara | iStock



"HAVE YOU NOTICED IT, TOO?"

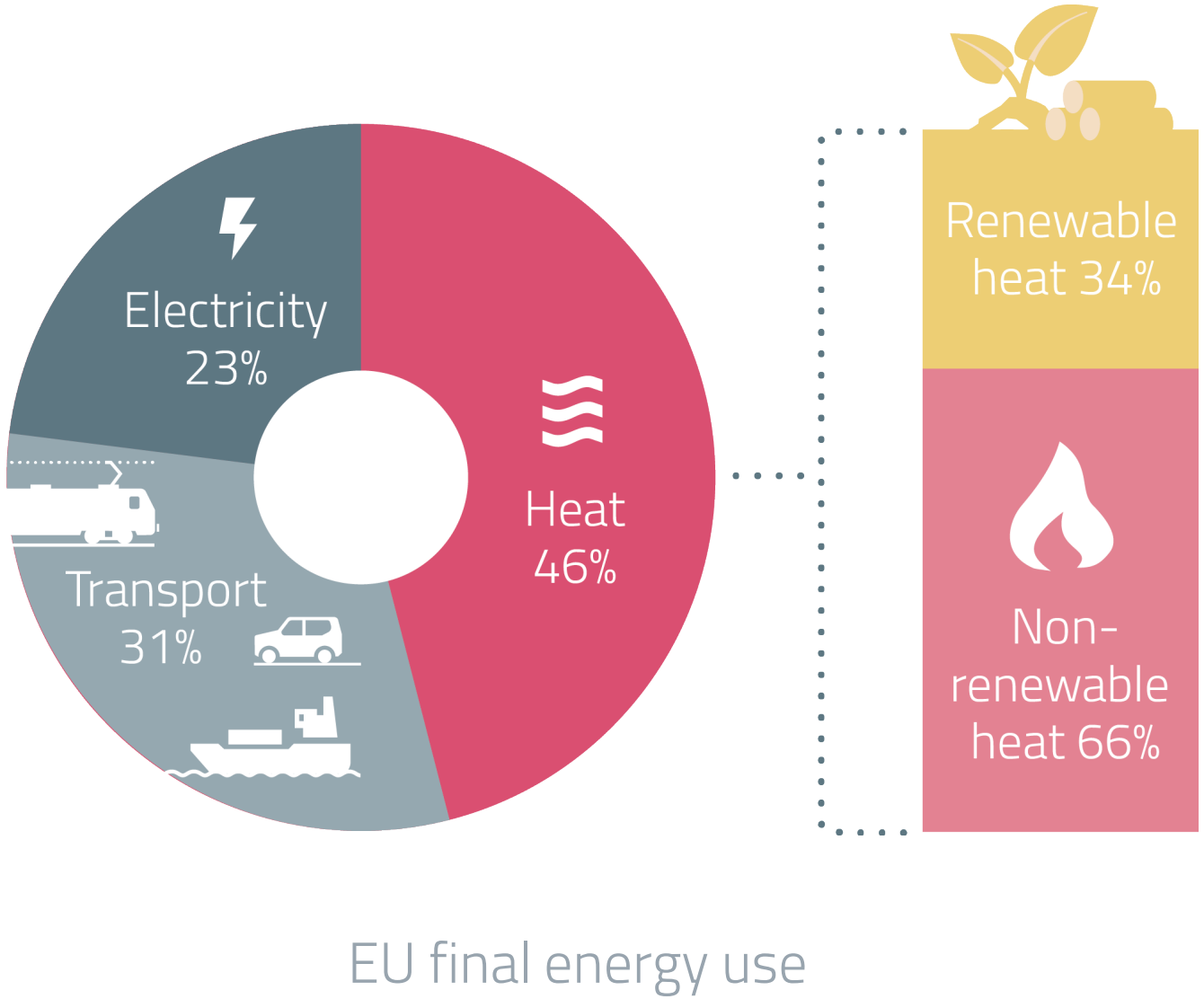
Industry is neglected in decarbonization policy



fcarchitects.org

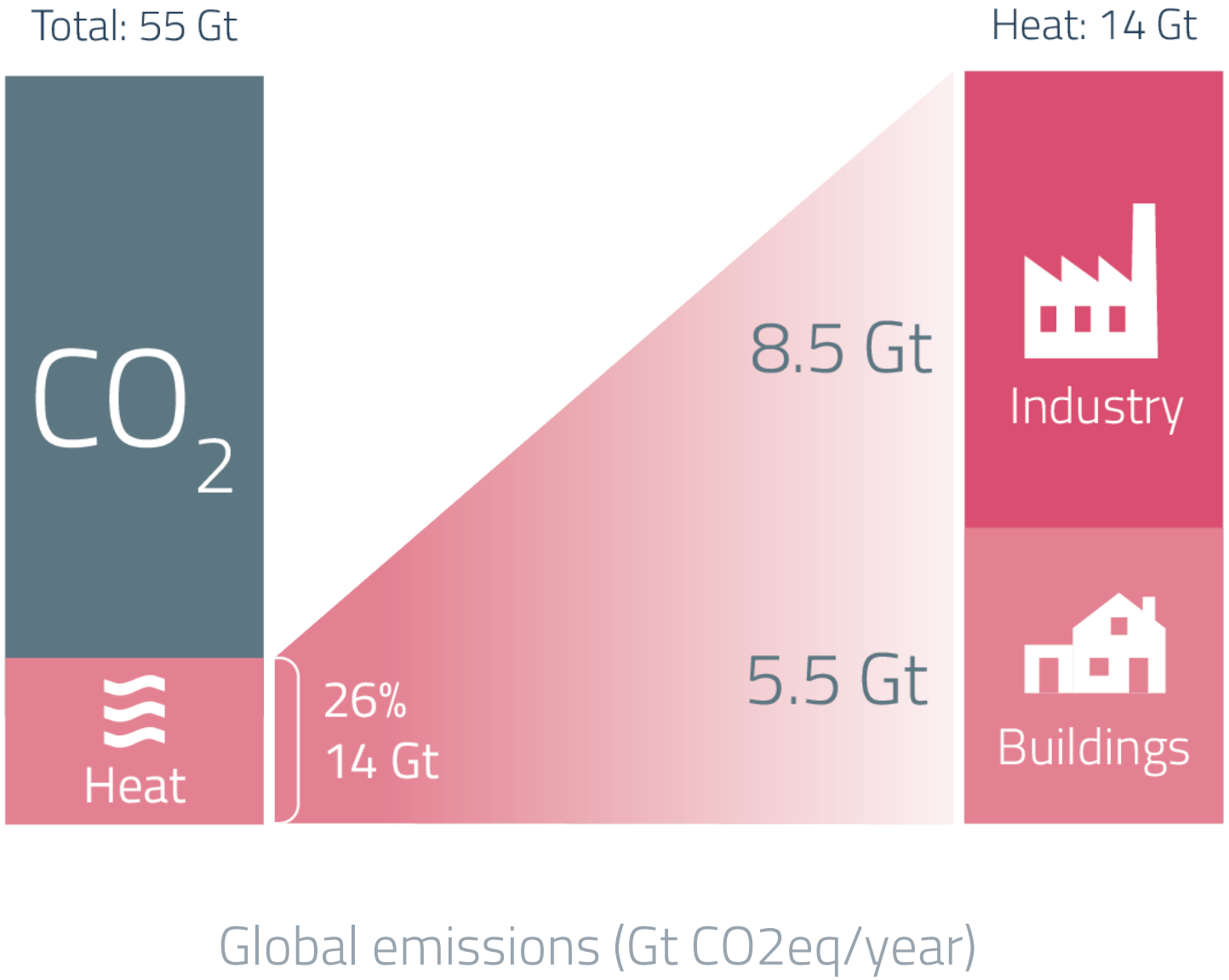
Source: raw data from Stechemesser et al and Our World in Data, **preliminary** analysis by FCA

Heat accounts for half of EU final energy use and is mostly fossil.

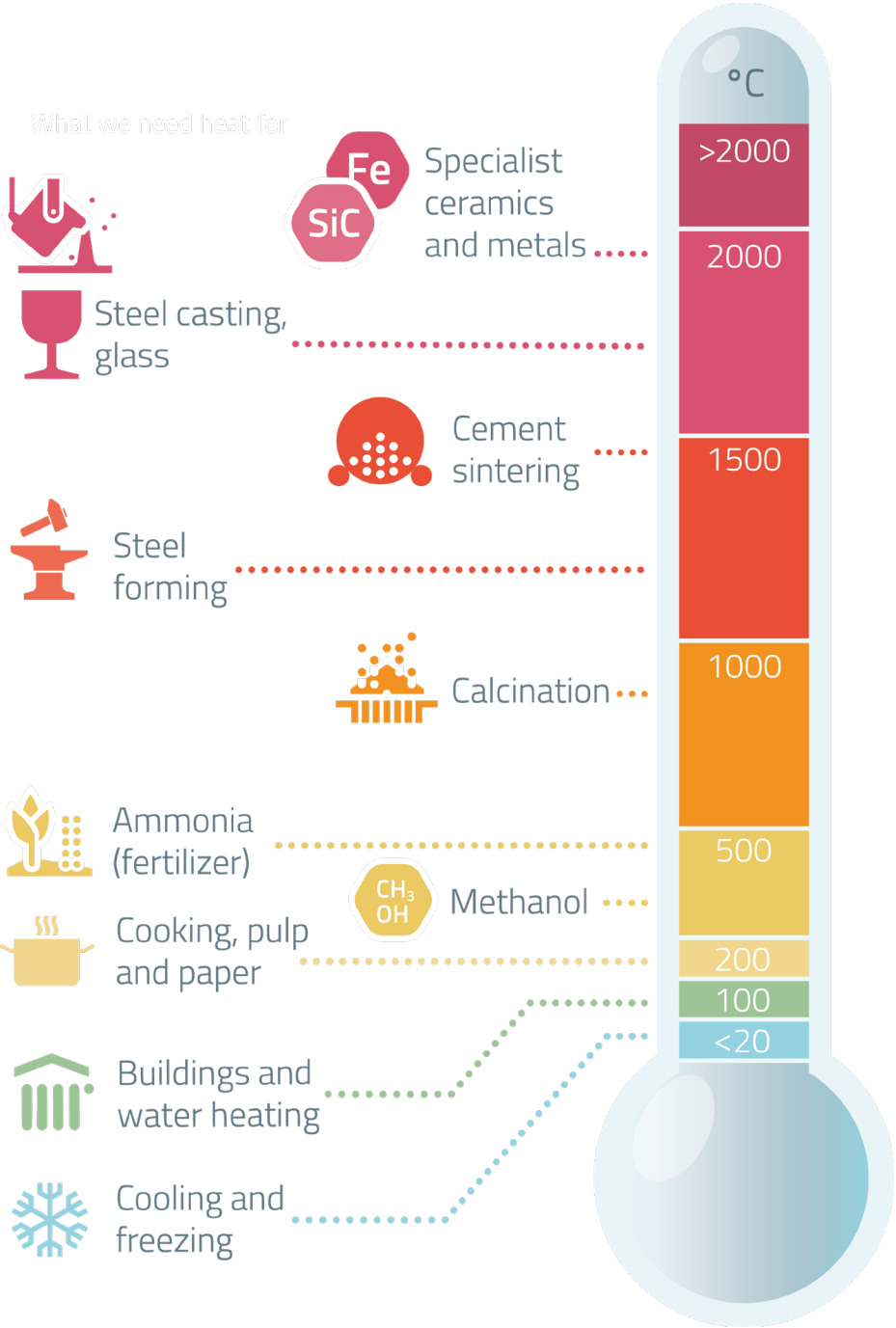


EU final energy use

Energy demand for heat generation is responsible for over 25% of global emissions

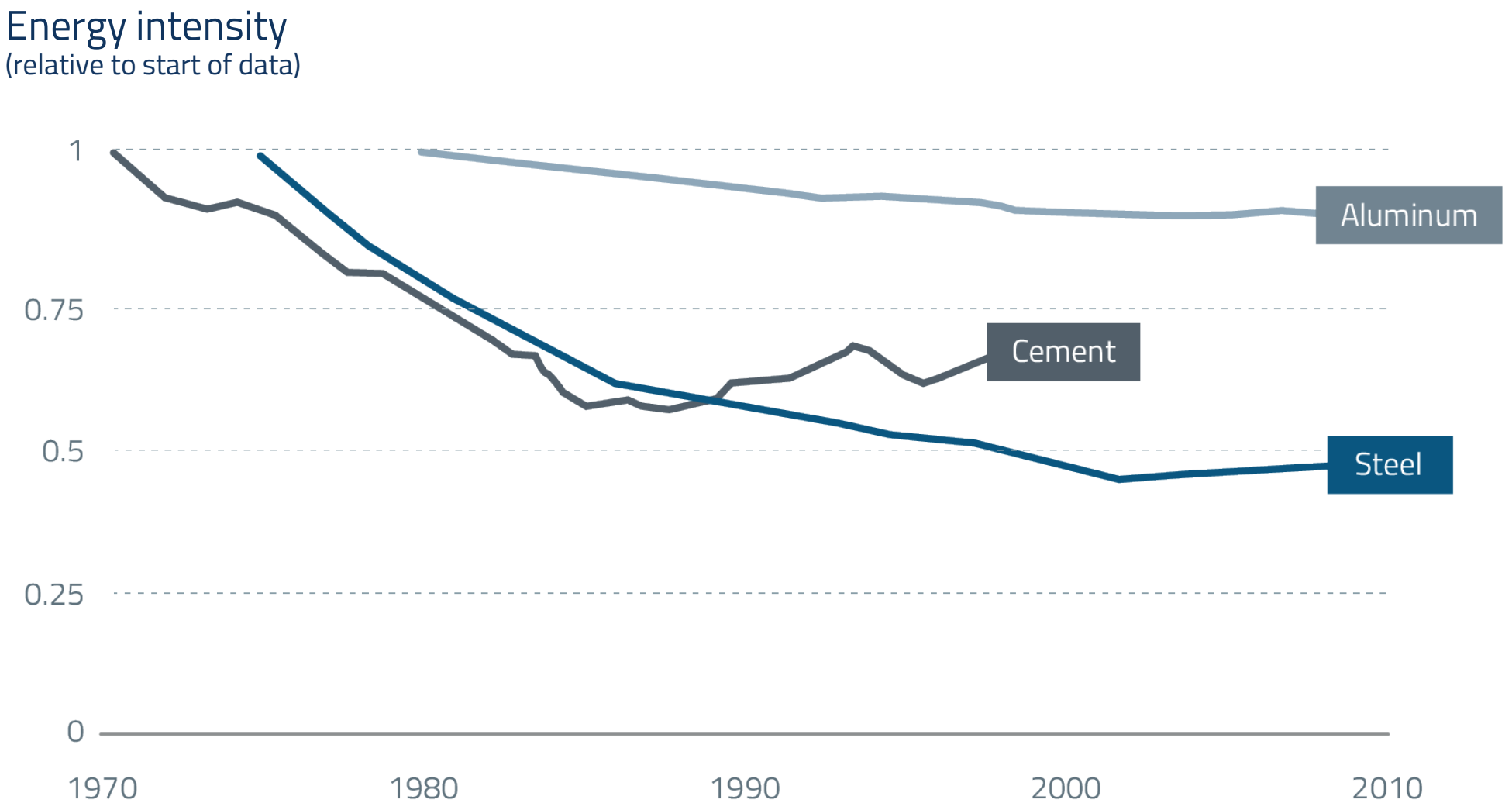


Heat demand spans a wide range of temperatures and products.



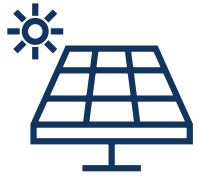
Many are building blocks of the energy transition.

Energy efficiency: indispensable but insufficient



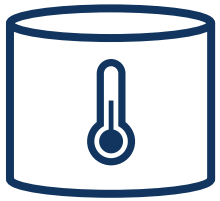
Source: Allwood and Cullen, 2018

Renewables + electrification + storage is a near-universal solution



1. Energy **source** that is low-carbon

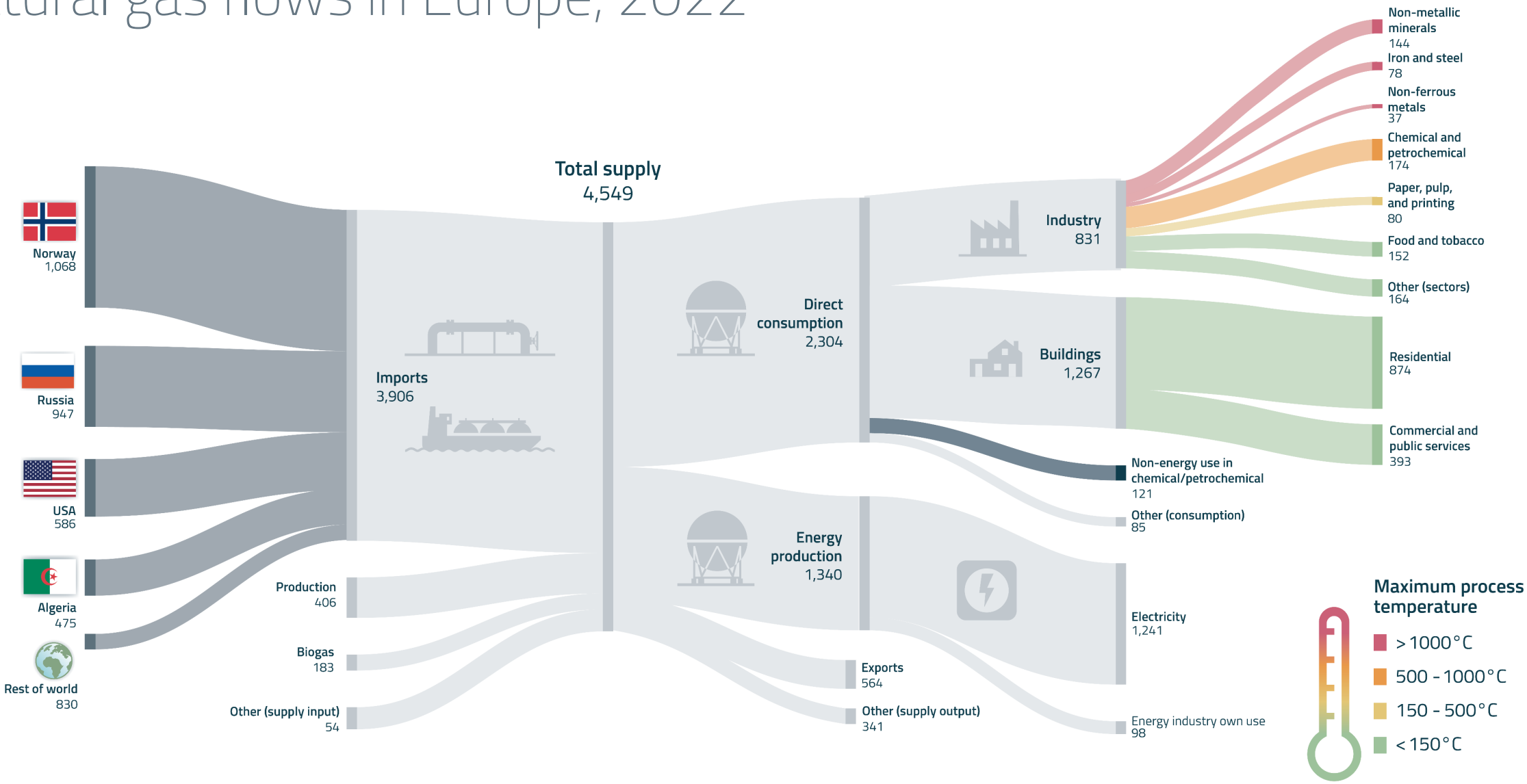
2. Energy **conversion** to heat



3. Energy **storage** (as heat)

A common fight: how to compete with fossil fuels

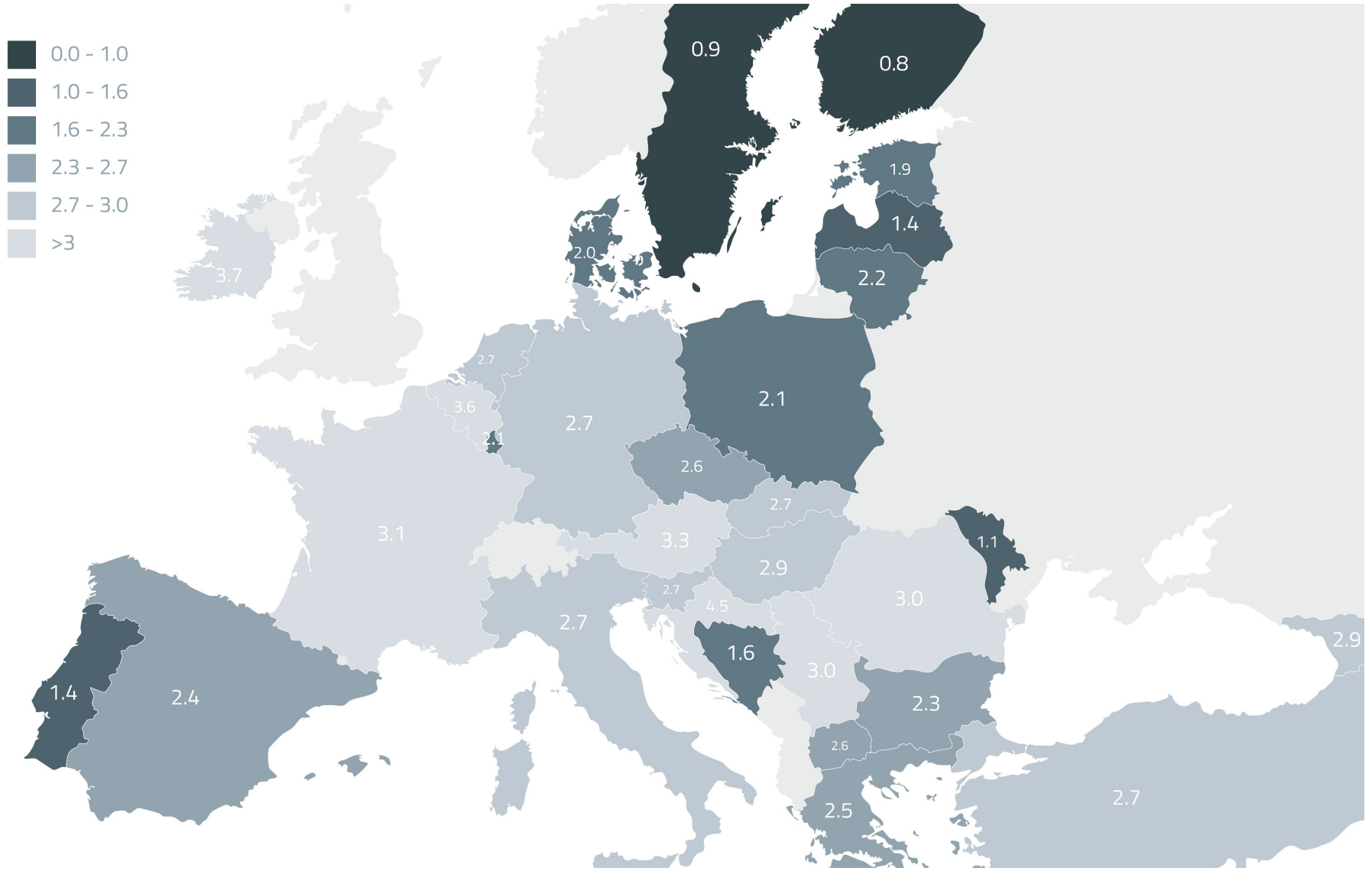
Natural gas flows in Europe, 2022



fcarchitects.org

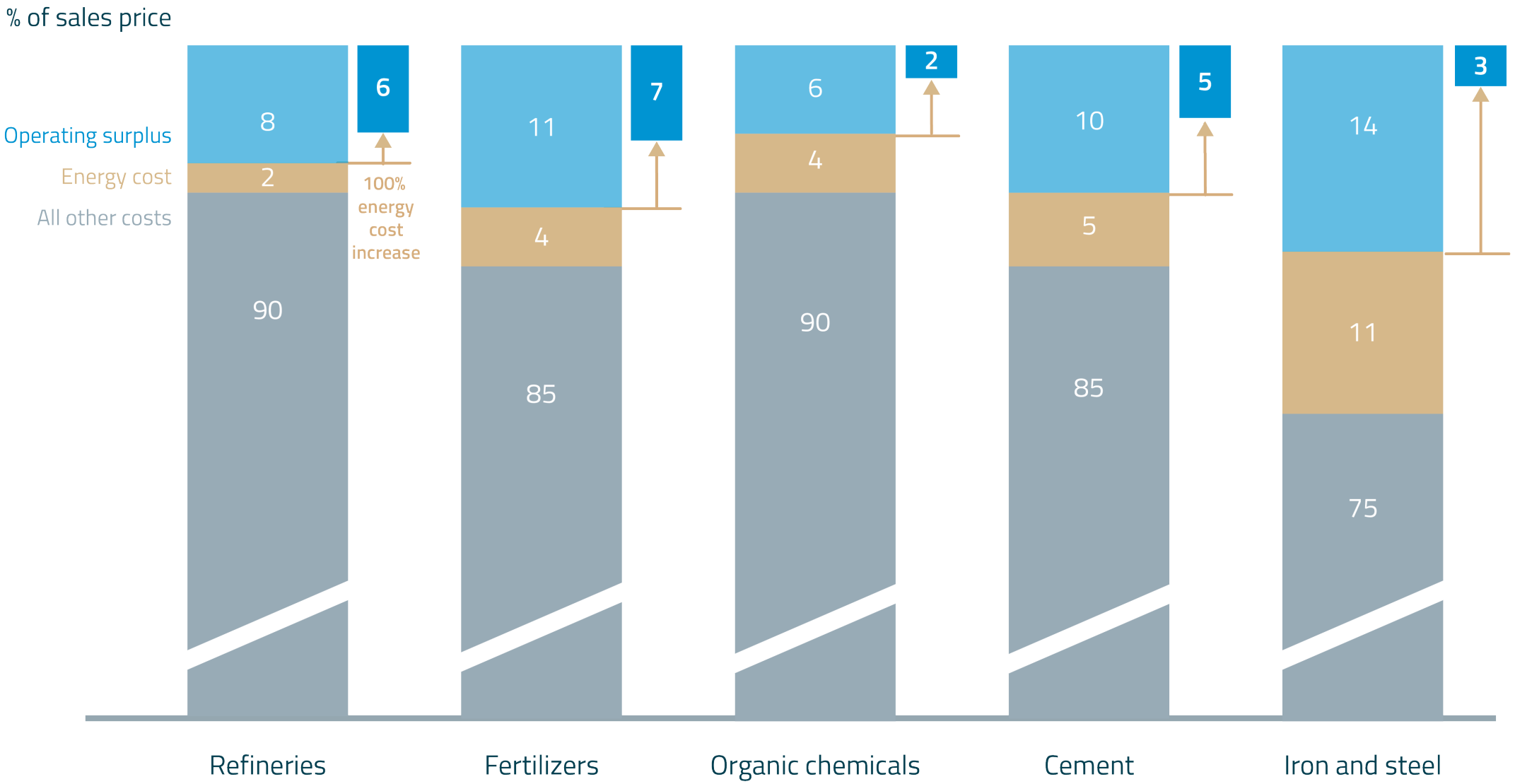
Source: Eurostat, 2022, EC Quarterly report on European gas markets Volume 15 and FCA analysis, EU-27

Electricity usually costs 2-3 times more than natural gas



Source: Eurostat

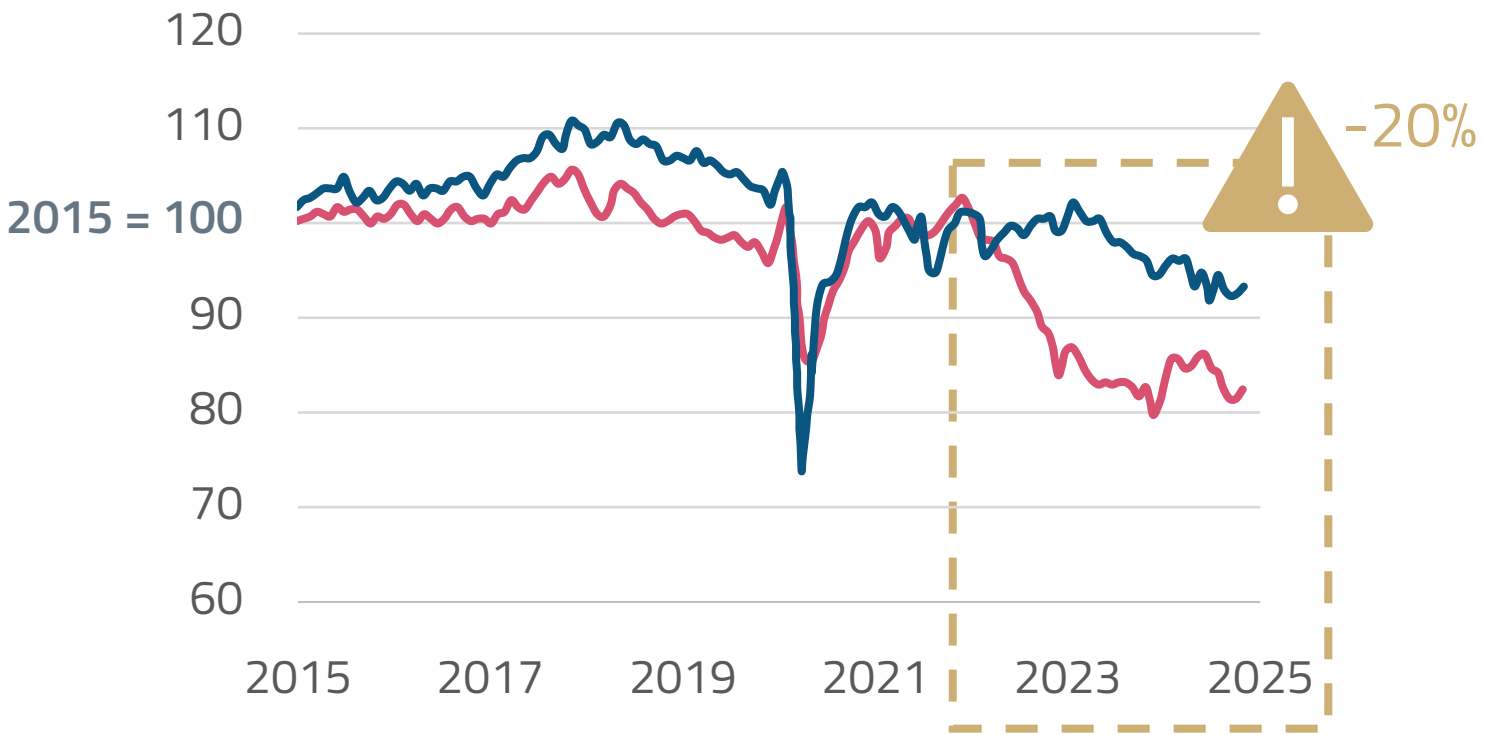
Energy-intensive sectors are sensitive to energy costs



Source: data from de Bruyn et al., 2020, Energy-intensive industries, analysis by FCA

The result of fossil dependency: price shocks hit hard

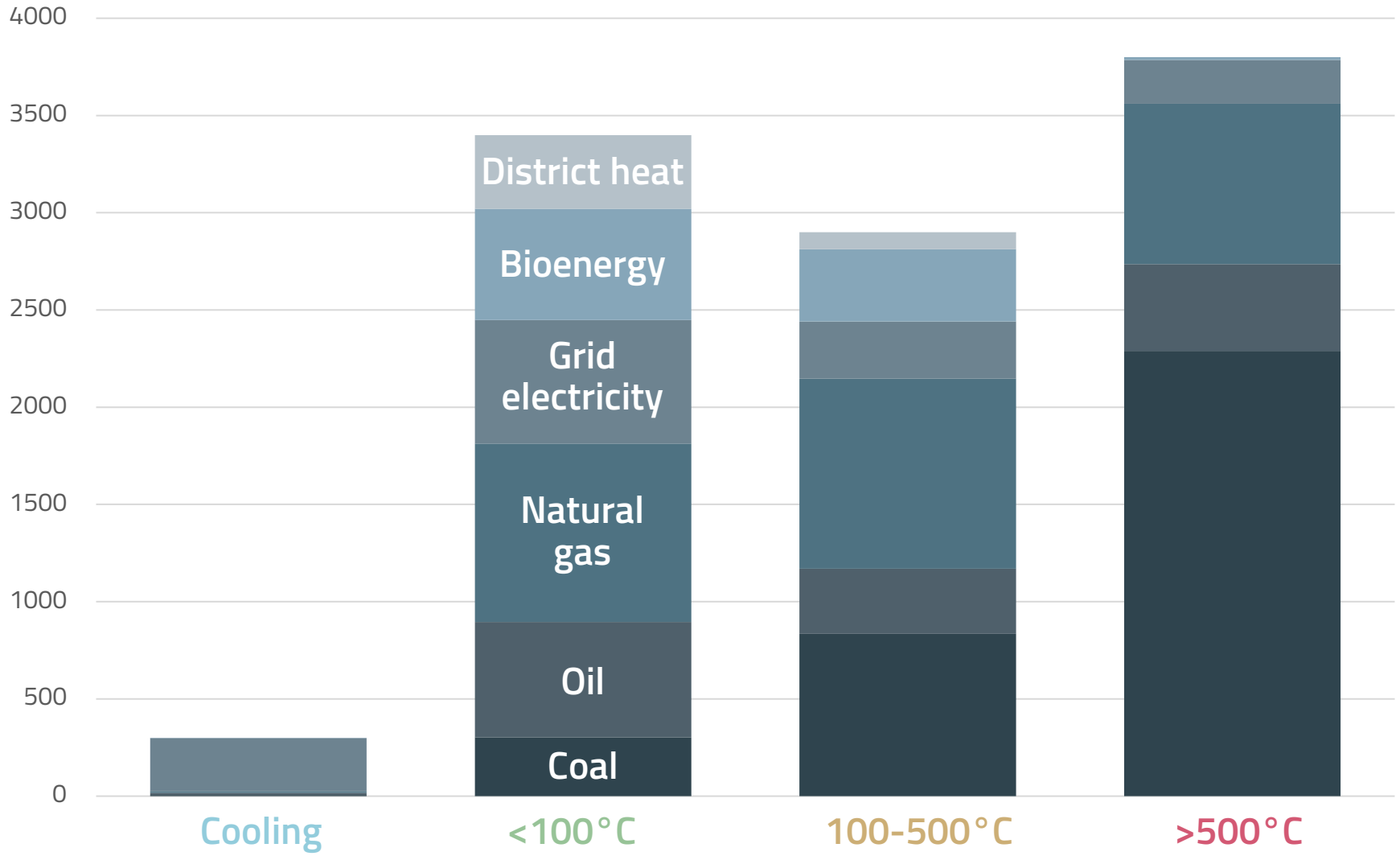
Production index **industry** and **energy-intensive industries** in Germany



Source: Statistisches Bundesamt (Destatis), 2025

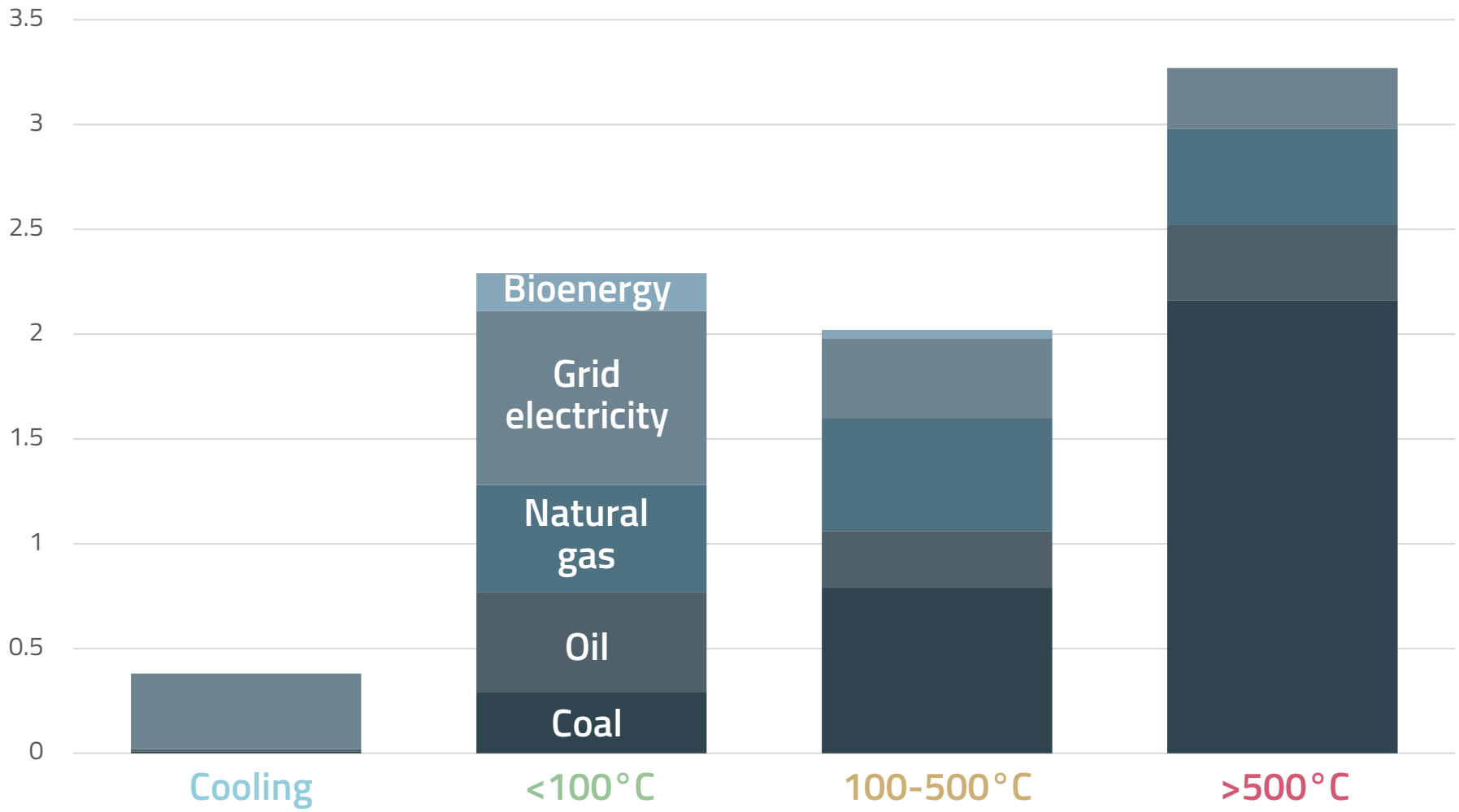

Characterizing thermal energy
demand across sectors

Energy use by source (EJ, globally, 2019)



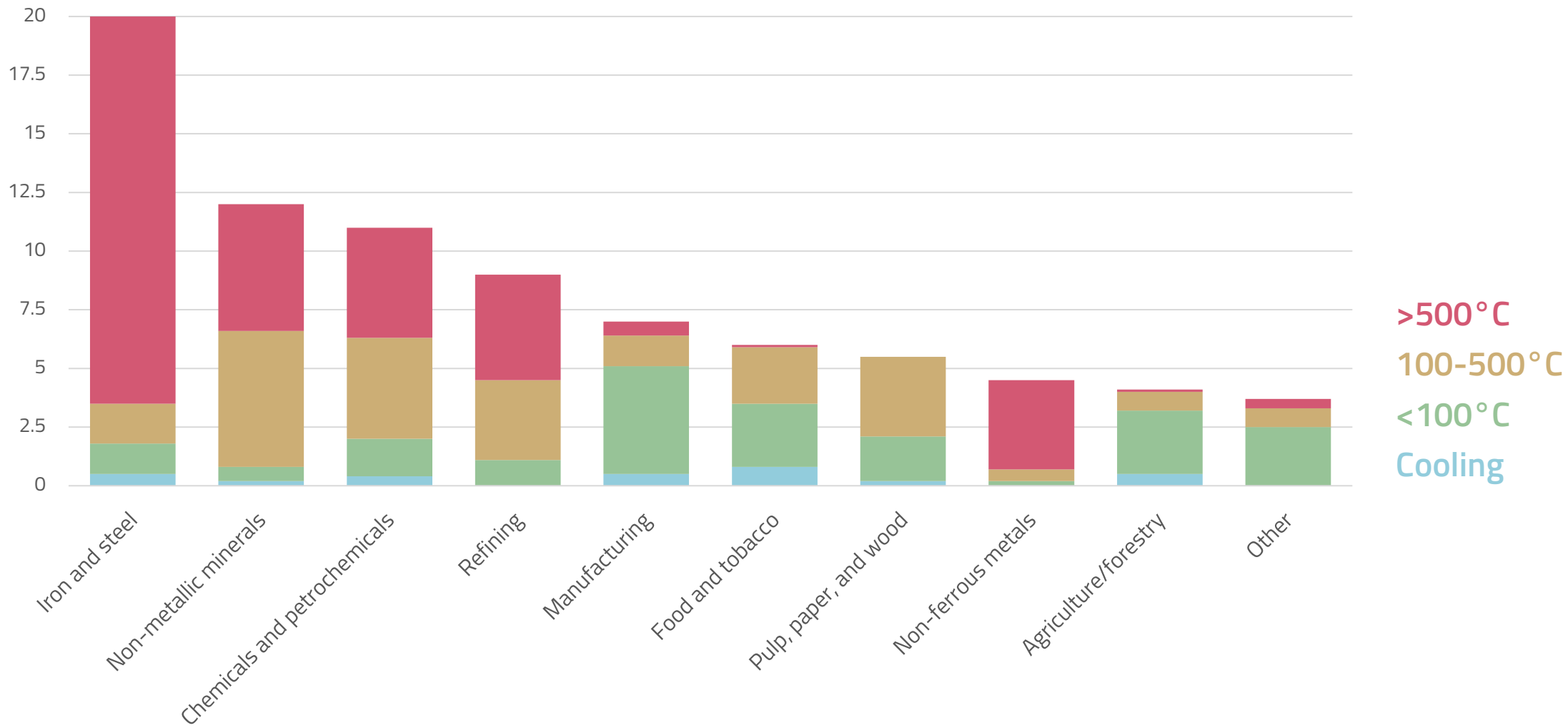
Source: data from McKinsey Global Energy Perspectives

Emissions ($GtCO_2eq$)



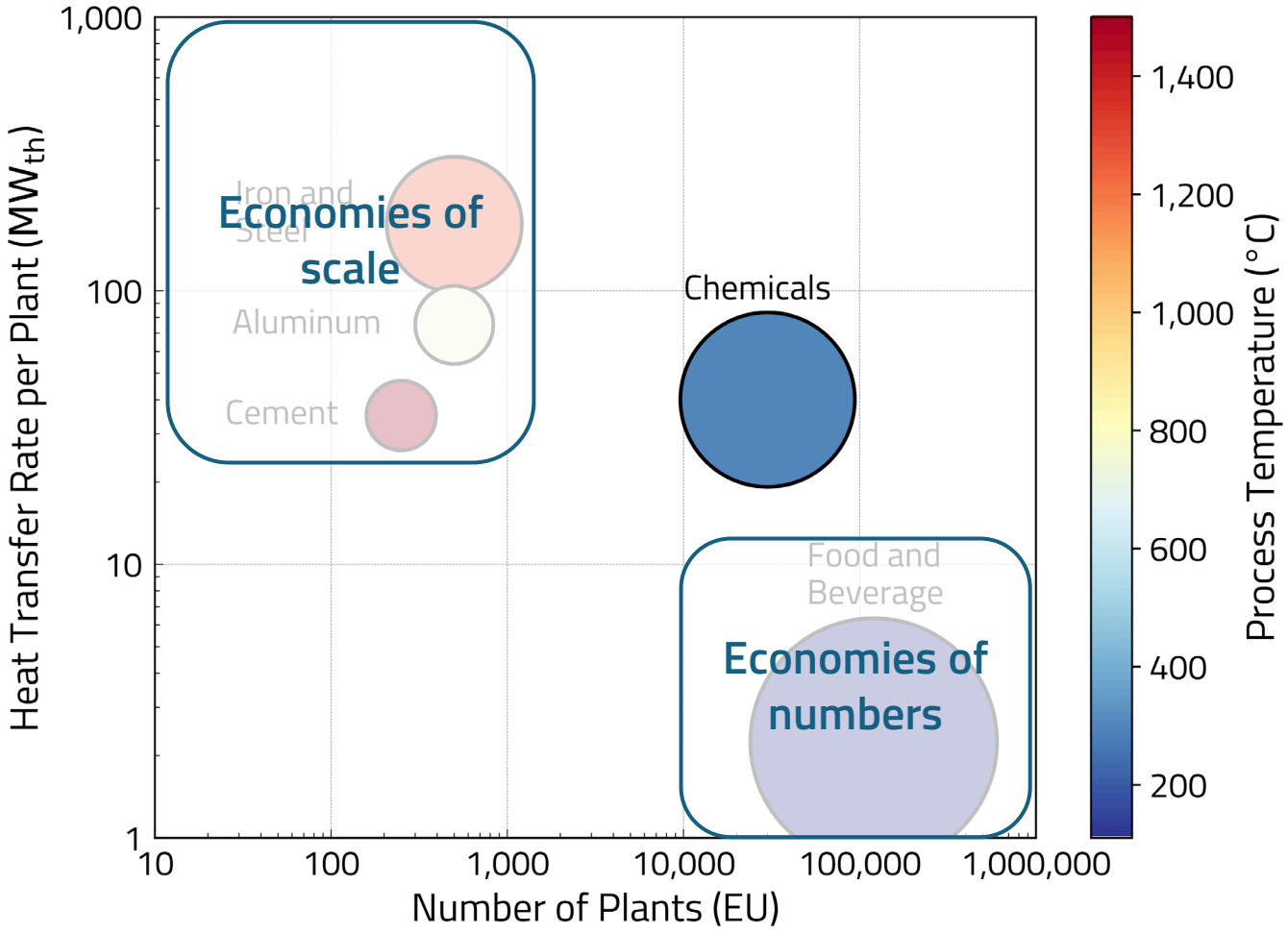
Source: FCA analysis

Energy use by sector (EJ, 2019)



Source: data from McKinsey Global Energy Perspectives
NB: ~20 EJ missing due to insufficient reporting

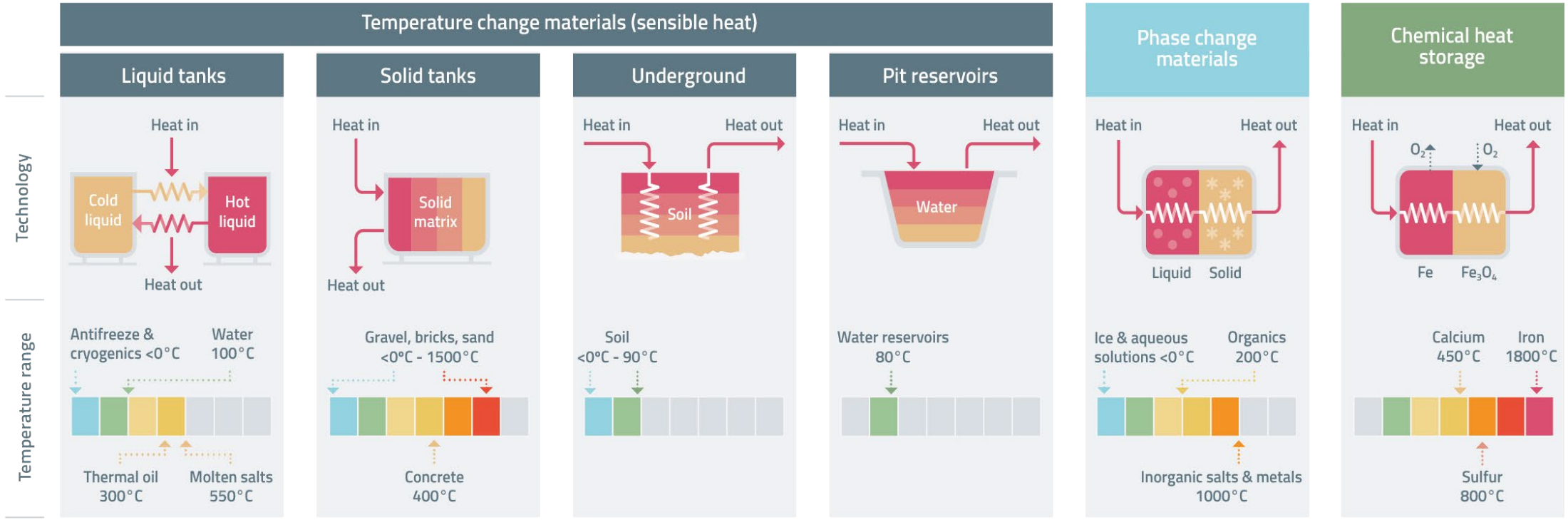
Low-temperature sectors will go first, then pushing to higher temperatures



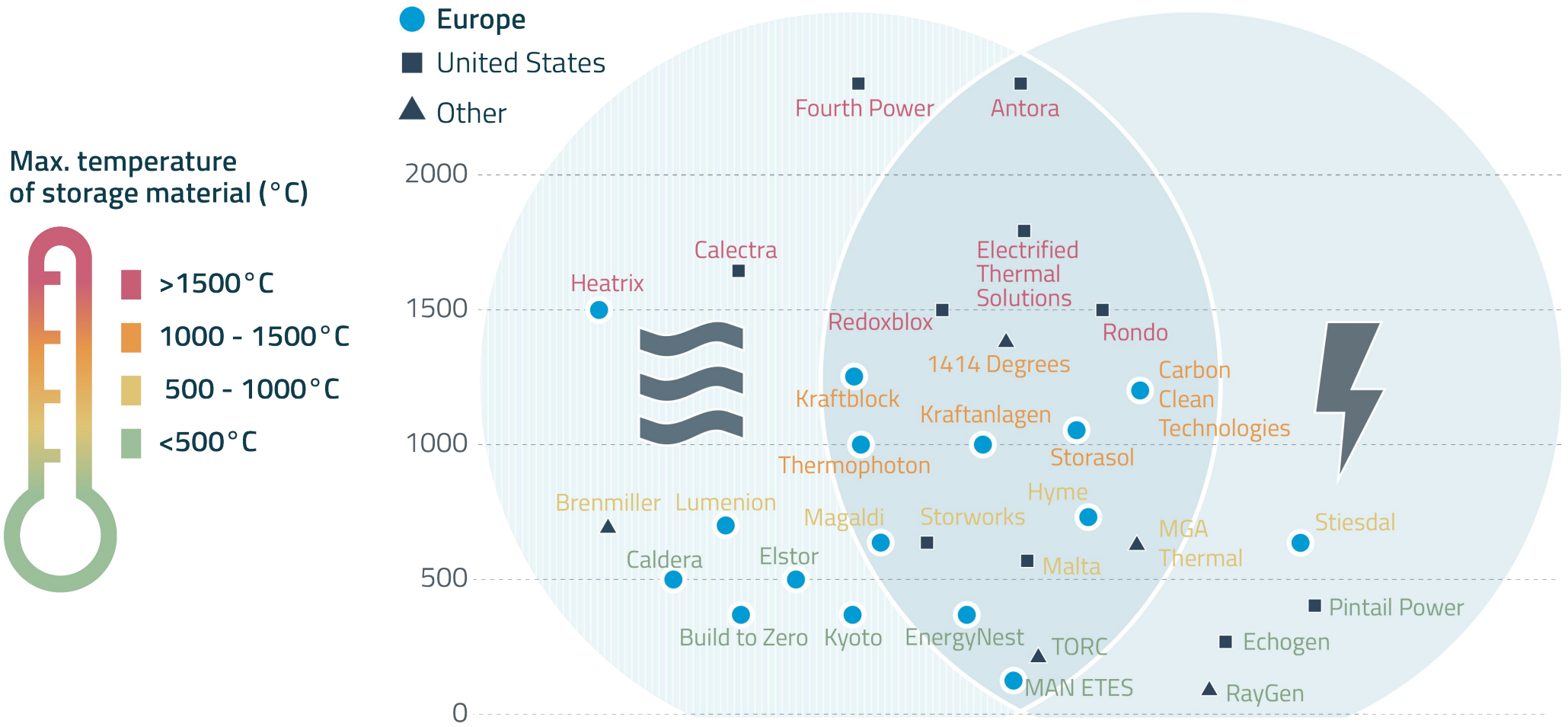
Source: Eurostat, European Commission, CEMBUREAU, INL


What does the design space
for thermal storage look like?

A vast design space: temperatures, materials, discharge…



… but the design space is well covered



Source: FCA

Now is the time to build.

Thank you for your attention!

FCA Future Cleantech Architects

Heat Demand in Practice: An Industrial Perspective

Johannes Haus

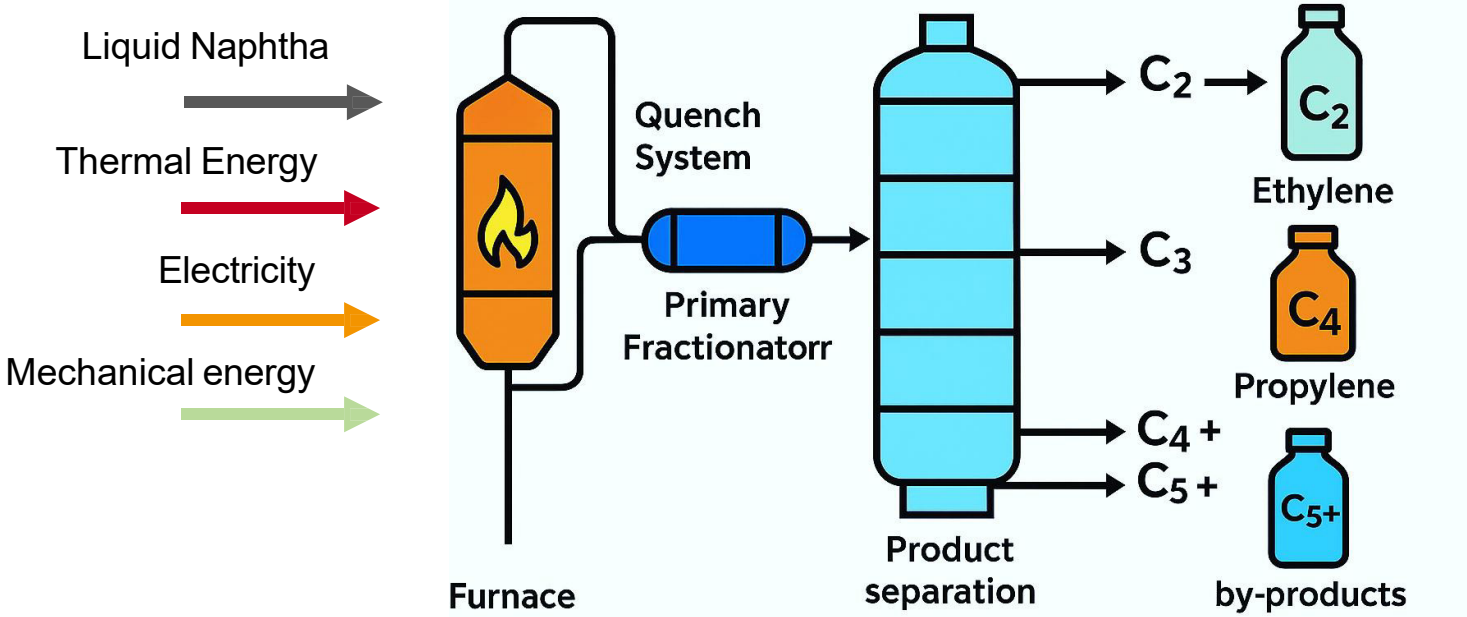
Technology Energy Supply, Carbon Abatement & Transformation Concepts, BASF SE

October 8th, 2025

BASF
We create chemistry

Chemical industry needs **high mounts** of **thermal, mechanical and electrical energy as well as C-atoms.**

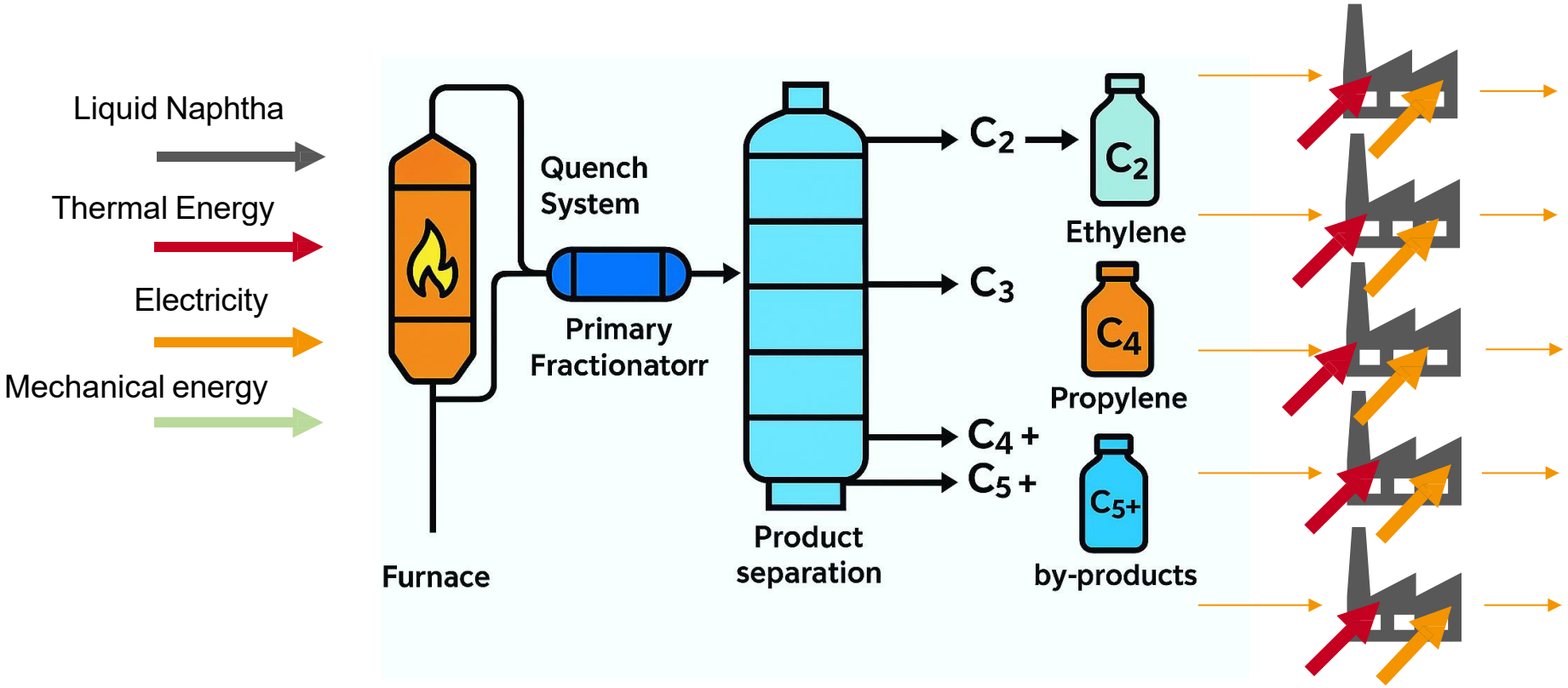
Steam cracking process
Core of BASF business



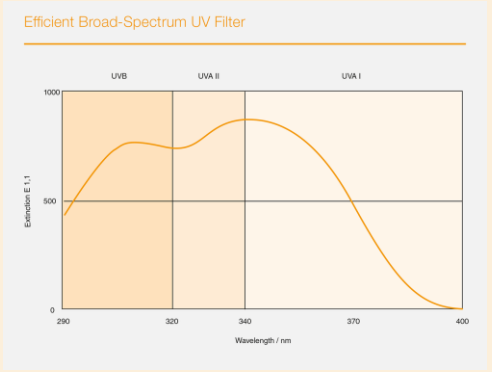
Steam cracker BASF Ludwigshafen

BASF
We create chemistry

BASF business model simplified



Vitamin A



Tinosorb S (UV-Filter)

Chemical industry perfectly **suited for (renewable) electrification** regarding power and heat needs.

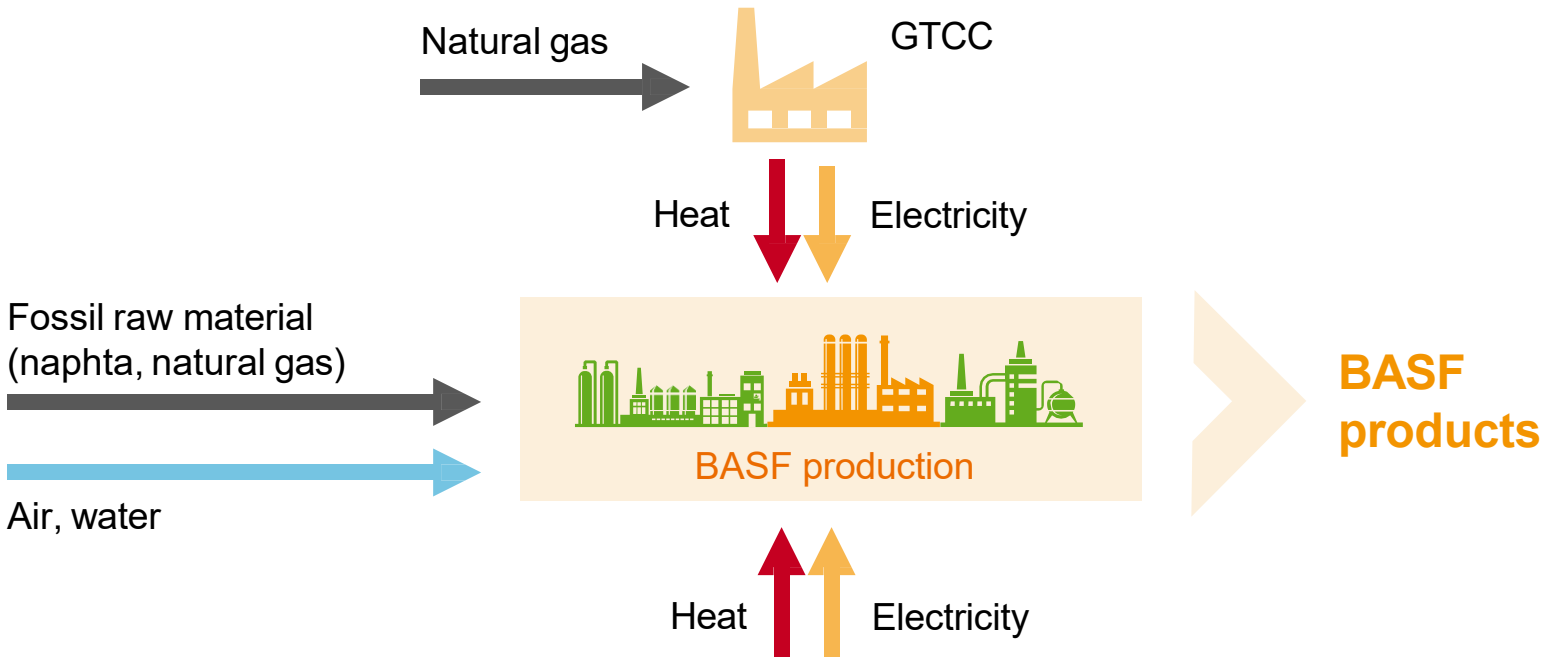
BASF
We create chemistry

BASF business model simplified

53 Million MWh Total energy consumption. 17 Million metric tons of CO_2 emissions in 2024.

Total energy consumption includes fuel demand in our own central power and steam generation plants, primary energy requirements in our process plants, and net power and steam imports.

To generate our own steam and power, we mainly use natural gas (78.8%) and substitute fuels (17.8%). In 2024 around 26% of worldwide electricity was from renewable sources (up 6% from 2023).



BASF has tremendous **demand for energy** (electricity and heat) as well as C-atoms as raw material.

BASF's expanded climate targets now cover a larger part of the value chaining

2030

25%
reduction in our absolute **Scope 1** and **Scope 2** CO_2 emissions
(compared to 2018)

15%
specific reduction in **Scope 3.1** CO_2 emissions
(compared to 2022)[1]

BASF's climate targets require tremendous decarbonization efforts on scope 1, 2 and 3.1 emissions until 2050

2050

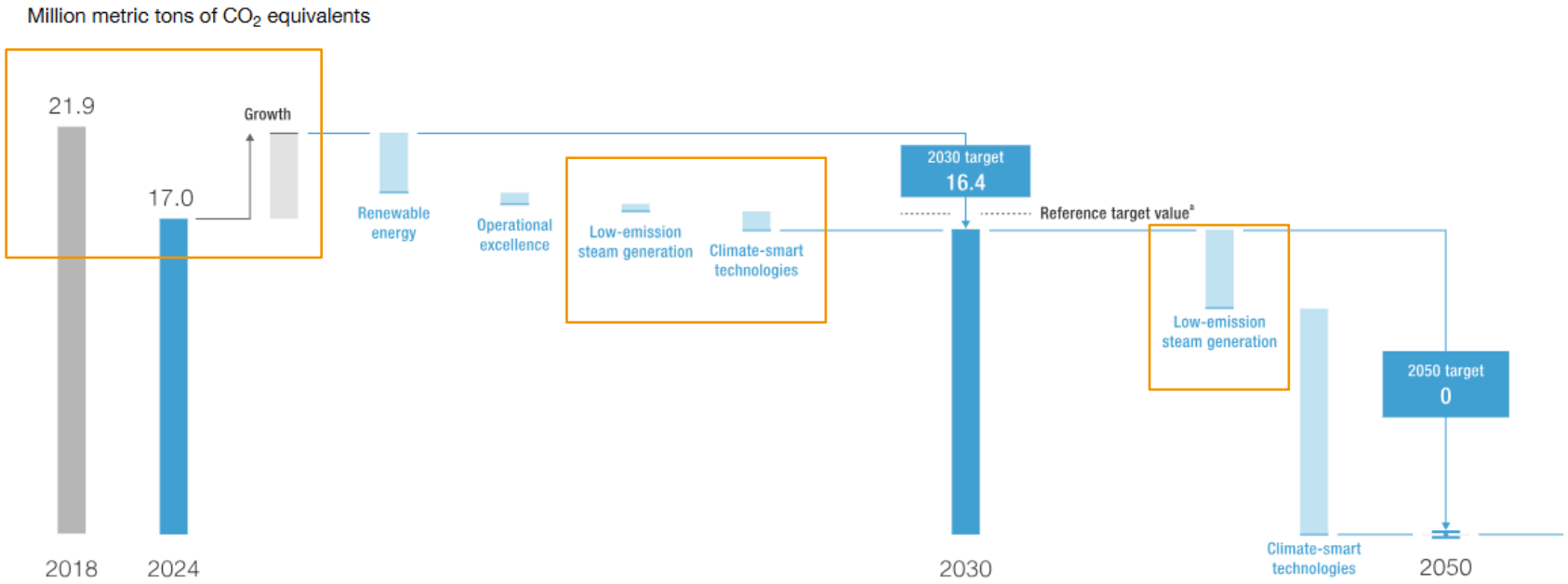
Net Zero
Scope 1, Scope 2 and **Scope 3.1** CO_2 emissions

Transition plan for climate change mitigtion

Main challenge, chemical industry in perfect storm

- High gas price in EU, high production costs
- Customer stockpiling, customer hesitation, trade barriers U.S.
- Overproduction CN, low margins in chemical industry

Currently low utilization of chemical plants especially in EU



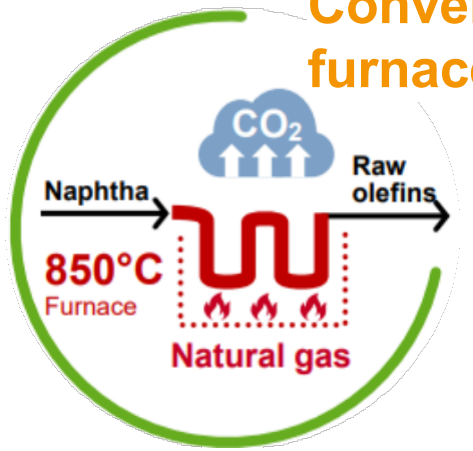
Currently low pressure to pursue emission reduction due to low emission from lackluster economic activity in the industry.

BASF
We create chemistry

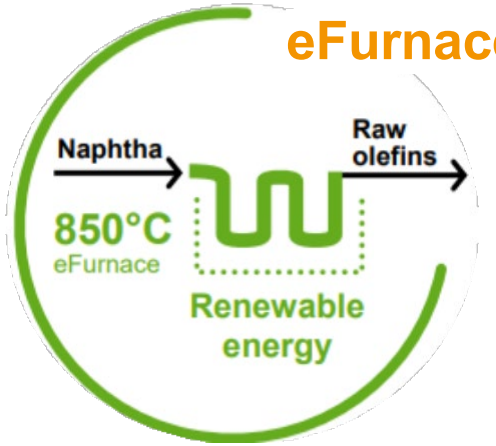
Climate smart technologies

E-furnace (Steam cracker)

Conventional furnace



eFurnace

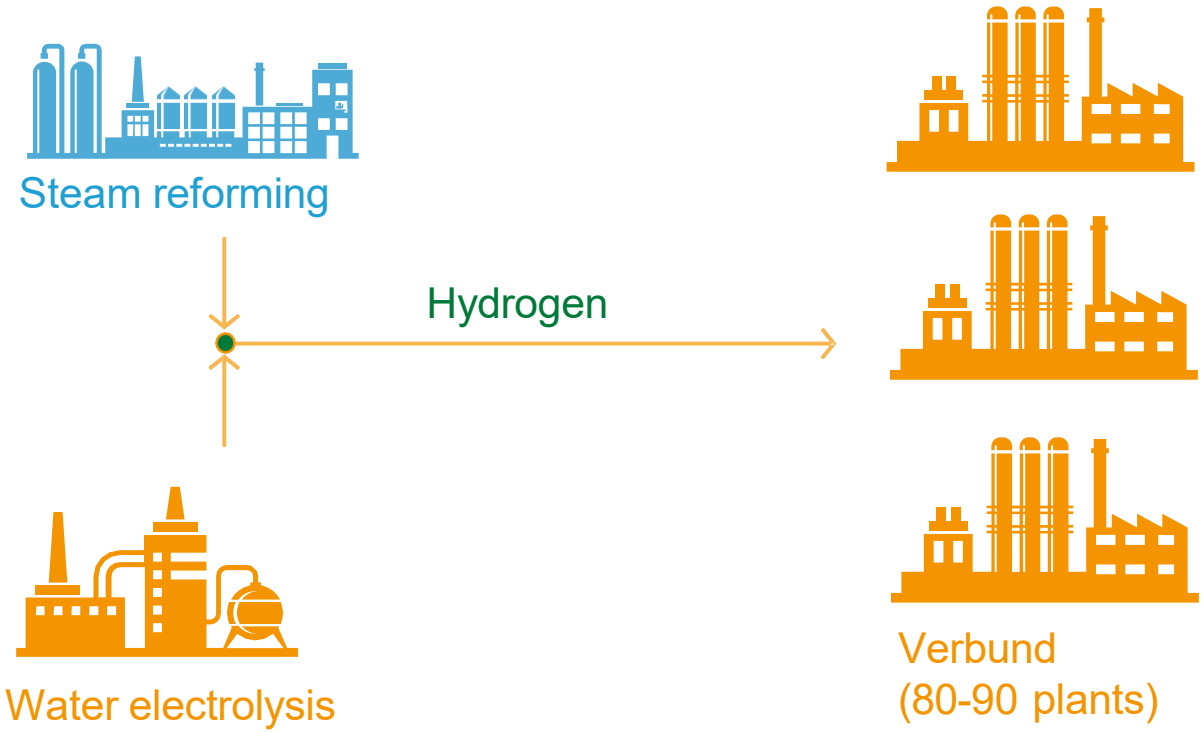


- BASF, SABIC and Linde build first electrically heated steam cracker (pilot) in Ludwigshafen
- Fully operational from April 2024
- Two furnaces, indirectly and directly heated, for 4 t/h Naptha and 6 MW heat power

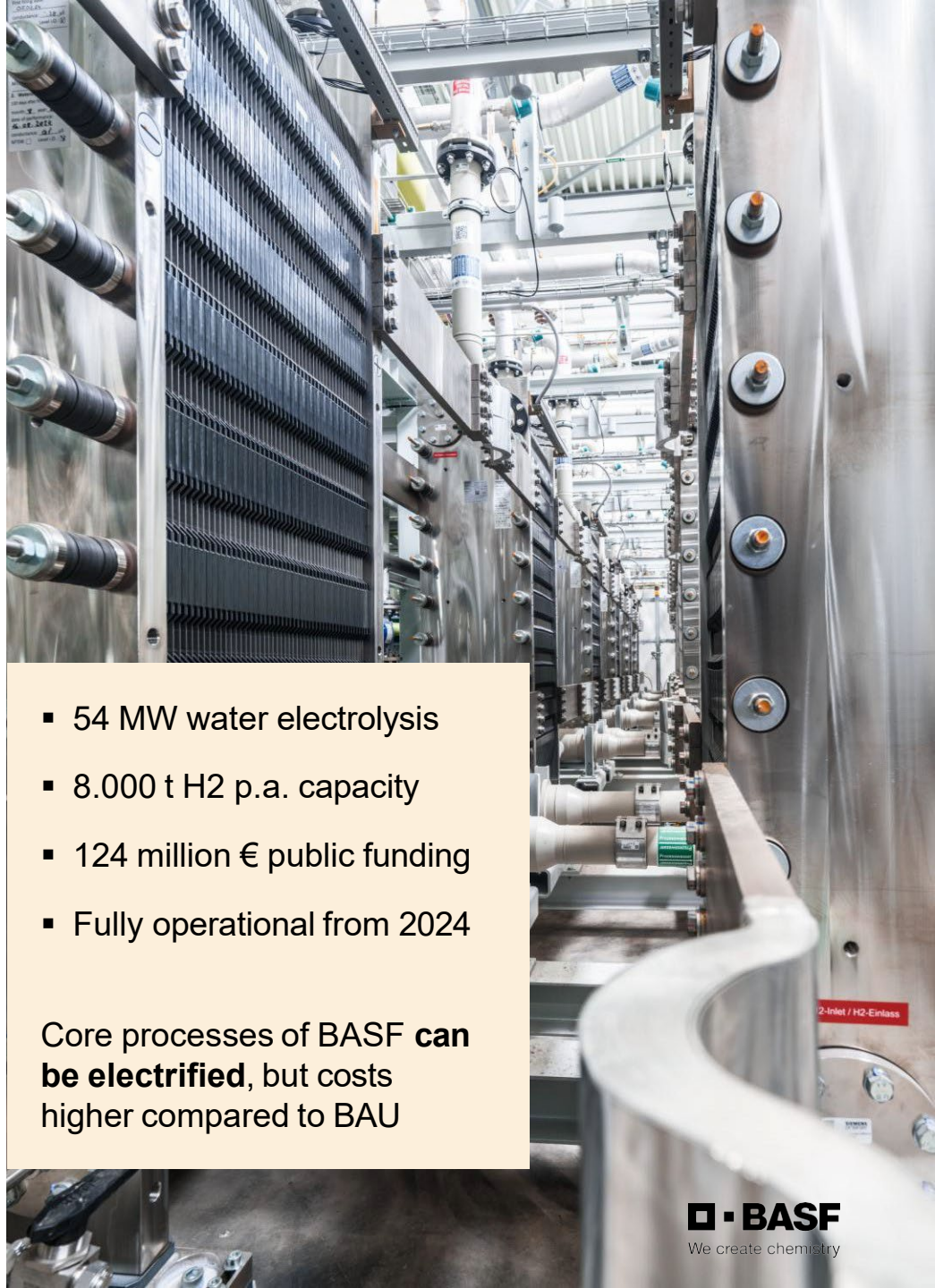
Core processes of BASF **can be electrified**

Climate smart technologies

Electrolyzer for H_2 generation



Water electrolysis is a commercially available technology but consumes large amounts of electricity



- 54 MW water electrolysis
- 8.000 t H2 p.a. capacity
- 124 million € public funding
- Fully operational from 2024

Core processes of BASF **can be electrified**, but costs higher compared to BAU

BASF
We create chemistry

Low emission steam generation

World’s largest heat pump for steam generation

Visualization of the CompriVAP technology for the large-scale heat pump at the BASF Ludwigshafen site.

- BASF builds world’s biggest 50 MW heat pump for steam at Ludwigshafen site with GIG Karasek
- 100.000 t p.a. of CO2 abatement
- Construction began, operational mid 2027
- 300 million € public funding

Activities strongly driven by public funding of projects.

Current projects

Electrode boiler to balance grid at BASF Schwarzheide

- 25 MW electrode boiler under construction until 2026
- TSO 50hertz to have full access to dump surplus electricity into boiler
- BASF must show a reduction in CO2 emissions from own plants at this time
- BASF must be ready to always accept electricity from TSO 50hertz (Redispatch)

Flexible/ hybrid solutions can pave way towards **broader implementation** from 2028

Current projects

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Flexible/ hybrid solutions can pave way towards **broader implementation** from 2028

Geothermal energy exploration at site

- BASF Ludwigshafen started 2D seismic evaluation of geological situation below site February 2025
- Plan: Extract geothermal water for steam production (300 MW) and lithium extraction
- Joint forces with Vulcan energy to extract lithium

Geothermal energy could supply baseload steam demand and fit into Lithium strategy of GER.

Thermal energy storage for BASF

Copyright: Kyoto Group

- Power-to-heat asset for complete replacement of fossil infrastructure
  - Better arbitrage possibilities compared to e-boiler operation
  - Higher investment costs compared to e-boiler require higher utilization (MWh heat delivered per year)
- Establish algorithm-based power trading to increase profitability

TES need to beat LCOH of fossil equipment.

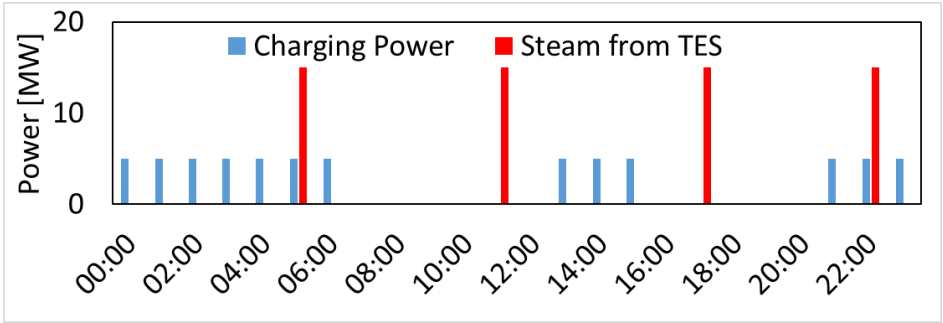
Lowering power prices and CAPEX remains key for roll-out.

Use case scenarios for thermal energy storage systems

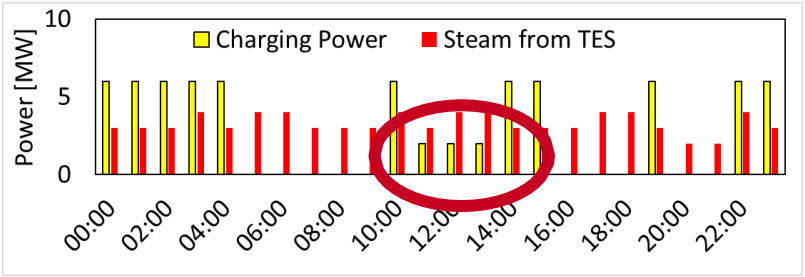
Use Case considerations	Description
Peak Shaving	Avoid high electrical peaks
Power price arbitrage (day ahead)	Use only 4-20 cheapest hours of power price
Power price arbitrage (intraday)	Capitalize on fluctuations in power prices on ID market with flexible asset
Ancillary grid services	Offer aFFR (automatic frequency restoration reserve)
Load shedding	Drop a high electrical load for grid stabilization
Surplus power consumption (§13 EnWG)	Consume surplus renewable energy from grid and demonstrate CO_2 reduction
E-boiler extension / Steam balancing	Use e-boiler steam at high pressure for charging TES and release at lower pressure
Introduction of own renewable assets	Use own assets to charge TES and avoid grid fees (behind-the-meter)

All measures aim for **economic improvement** of TES.

Peak demand shaving with power price arbitrage



Reduction of charging power for grid services



BASF
We create chemistry

The highest level of purity and quality for molten salt applications – BASF salt business

Purity

Our synthetic sodium salts, which contain a low chloride and magnesium content, ensure the highest purity and quality on the market.

Reliability

BASF has been reliably producing sodium nitrate and nitrite for over 100 years.

Expertise

- Salt Bath Reactors at BASF and elsewhere run with HITEC containing BASF salts since decades.
- More than 10 solar power plants delivered with BASF's sodium nitrate.
- Extensive collection of data for different molten salts in BASF's research facilities.

BASF is an **innovative and highly reliable supplier** of **high-quality heat transfer** and **thermal energy storage salts**.

BASF
We create chemistry

Way forward

Decarbonization until 2030

had **committed to CO2 emission reduction** targets by 2021

almost half have defined **Scope 3 emission targets**

Consumers to drive demand for low PCF products.

BASF
We create chemistry

Way forward
Decarbonization until 2030

BASF and Henkel join forces to substitute fossil feedstock in Henkel‘s Laundry & Home Care And Beauty Care Products

- Henkel will substitute fossile with renewable carbon feedstock from BASF
- Strong cooperation of BASF and now rollout on many products
- Ultimately, around 110.000 tons per year of ingredients will be substituted with renewable carbon sources with BASF’s biomass balance approach
- The program will ramp up quickly and avoid aoround 200.000 tons of CO2 emissions in total

Market-driven approach to decarbonize heat and products in focus.

BASF
We create chemistry

Way forward
Decarbonization until 2030

- BASF’s chemical production uses large amounts of electricity and heat, resulting in high energy consumption and CO_2 emissions
- The company aims to significantly cut emissions by 2030 and 2050, requiring major technological changes, but current economic performance slows development
- New projects include electric steam crackers, hydrogen electrolysis, and a massive heat pump, most supported by public funding
- Flexible solutions like electrode boilers, geothermal energy, and thermal storage are being developed to replace fossil fuels
- Customer need for abatement will drive new projects
- Economic and regulatory factors are key, as the industry faces high costs and competitive pressure in Europe

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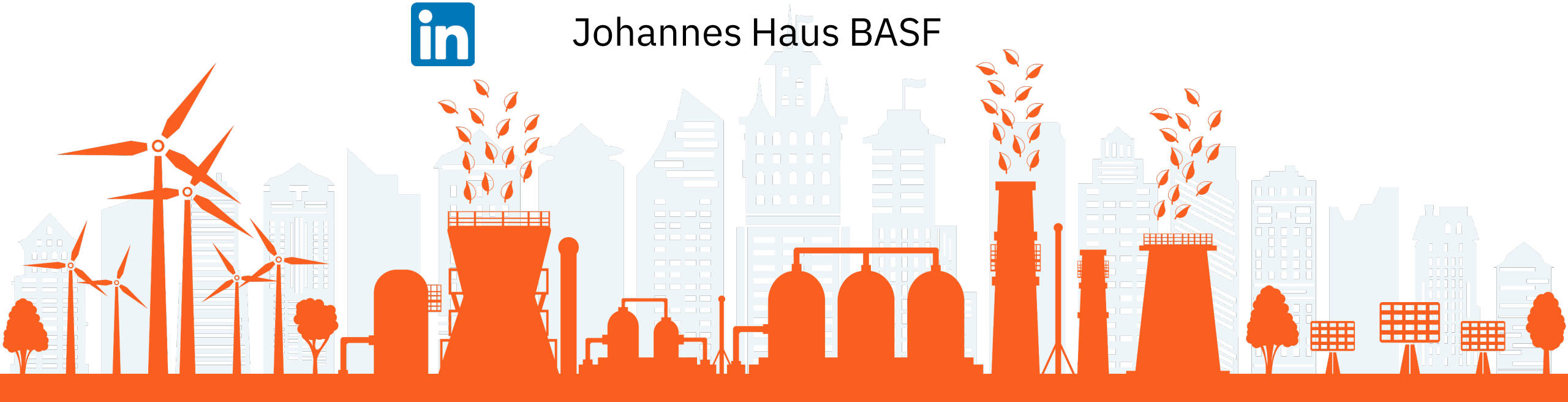
THANK YOU!

Johannes.haus@basf.com

Johannes Haus BASF



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Session 4

Trading Thermal Flexibility – Unlocking New Value Streams

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Monetizing Flexibility: Trading Opportunities for Thermal Assets

Ramona Wendtner

Senior Business Development Expert at enspired

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Enspired - Europe’s leading flexibility optimiser

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Storage optimization to maximize your asset’s performance

with our proprietary, AI-based, self-learning optimization platform

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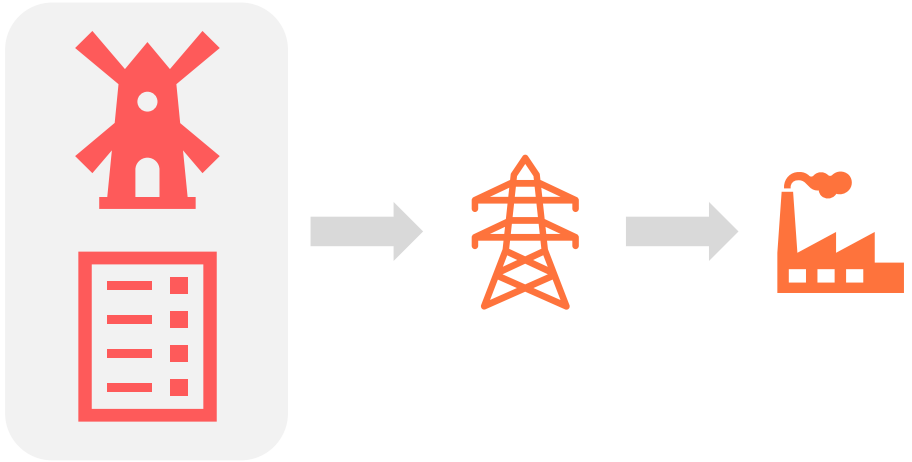
The basics

Market optimization is an alternative, low-cost procurement strategy

Electricity as a fixed cost

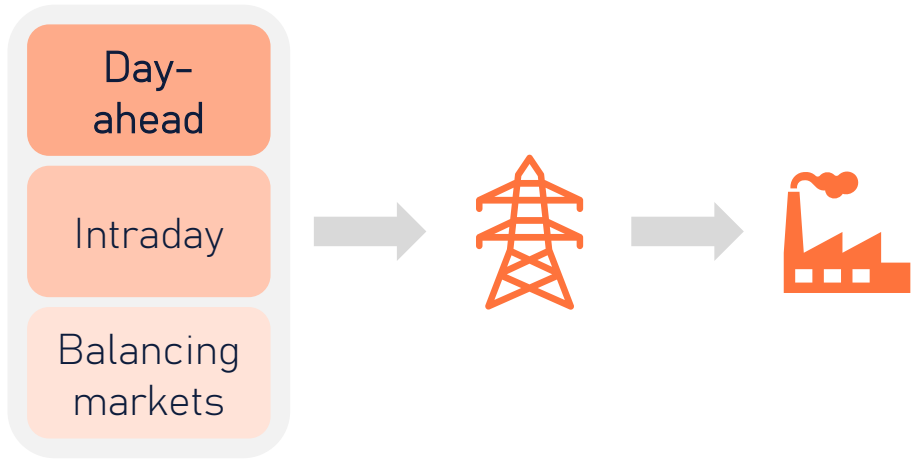


- PPAs or offtake agreements with large suppliers is industry standard
- Electricity procurement as a cost of approx. 50-120 EUR/MWh depending on the supply profile*

*from 10 year pay-as-produced PPA in GER to average DA price 2023-24

VS

Electricity as a cost optimization



- Short-term electricity markets i.e. wholesale (ID + DA) + balancing markets as an alternative
- Optimisation of procurement across all markets provides arbitrage opportunities + revenues

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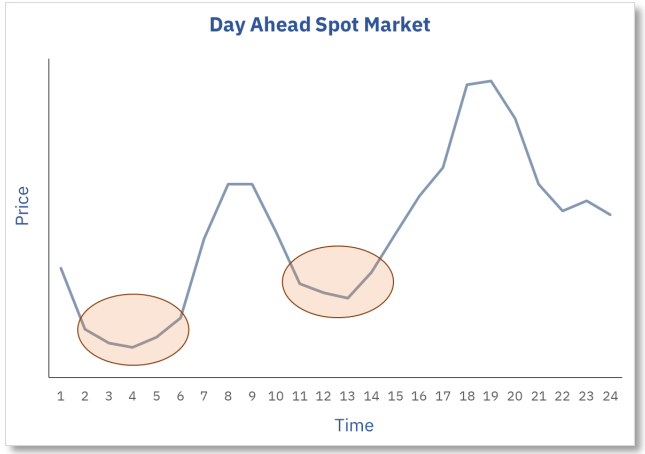
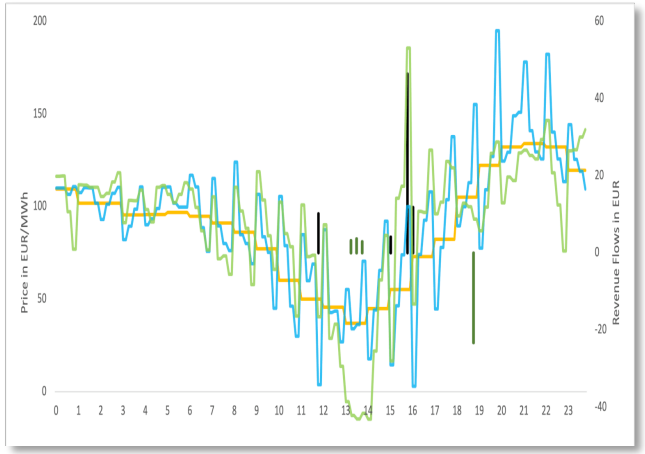
We maximize value across all accessible power markets

Sourcing power in the
Day-Ahead Market (DA)



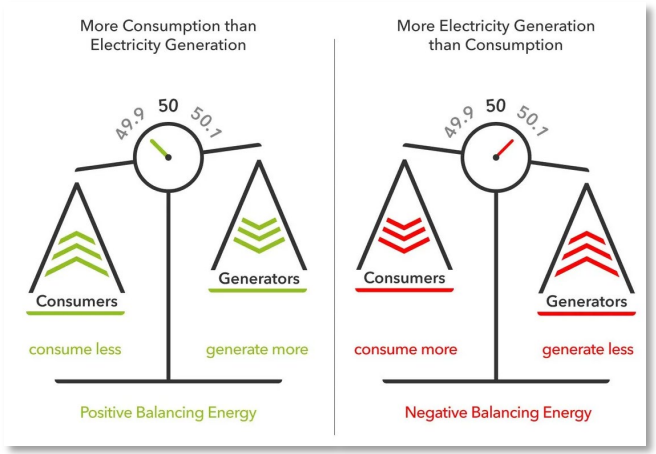
Utilizing the price volatility
to source low-priced power

Optimizing cost in the
Intraday Market (ID)



Reducing the power cost
by continuous trading

Additional revenues in the
Ancillary Services (aFRR)



Revenue by being available
for balancing of the grid

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The enspired approach

Enspired's optimization approach makes TES more competitive than gas

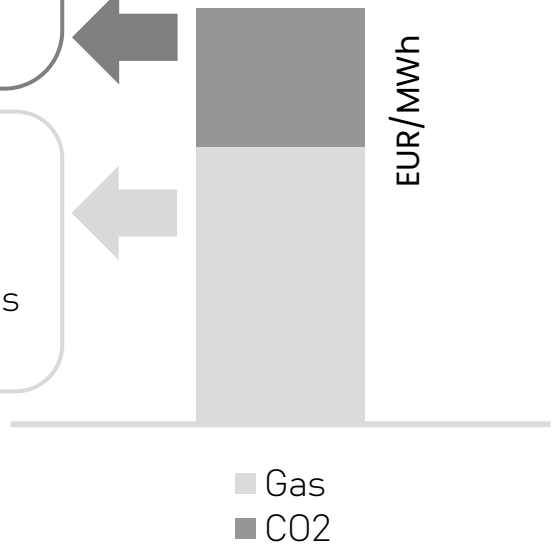
LCOH of Gas

Increase carbon costs

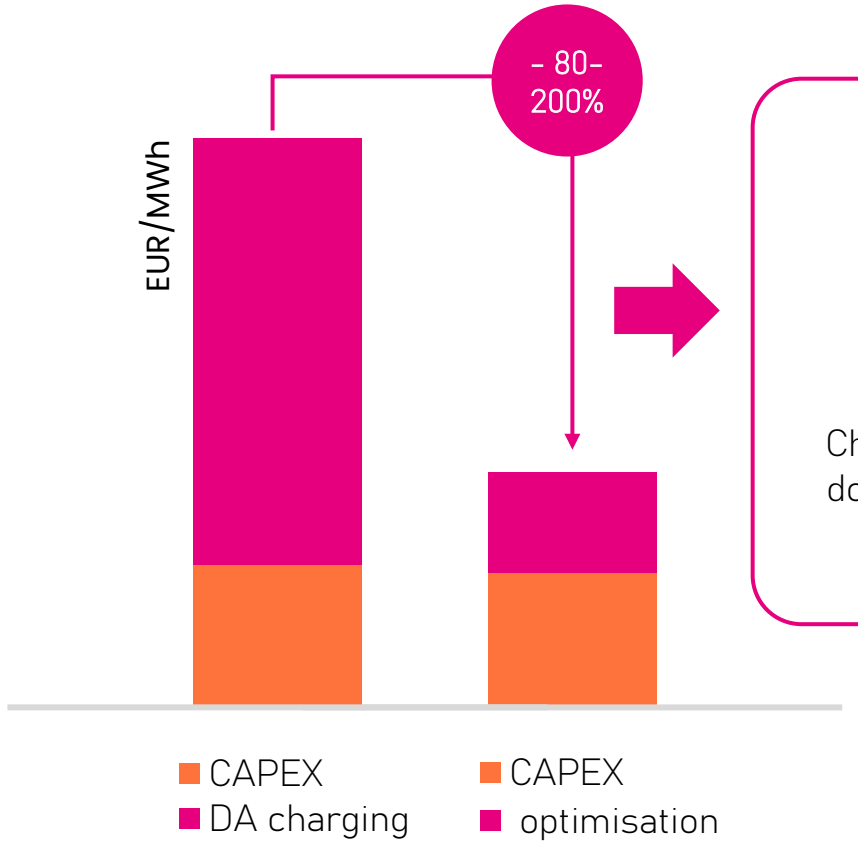
Prices of 20-25 EUR/MWh + expected to rise in EU

Volatile gas prices

Costs of ~ 40 EUR/MWh with prices remaining volatile



LCOH of Thermal Storage



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enspired x-market optimisation

Charging on WS + aFRR down **reduces the costs by up to 200%**

Optimisation of TES on WS + balancing markets

1. aFRR down capacity allocation within asset boundaries

2. Free bids on aFRR energy

Number of Trades
2787

3. Re-optimization of 15 min products on IDC

4. Physical energy dispatch on ID/DA

Optimisation of a 20 MW, 4h thermal storage asset in summer 2025 with flat heat demand profile

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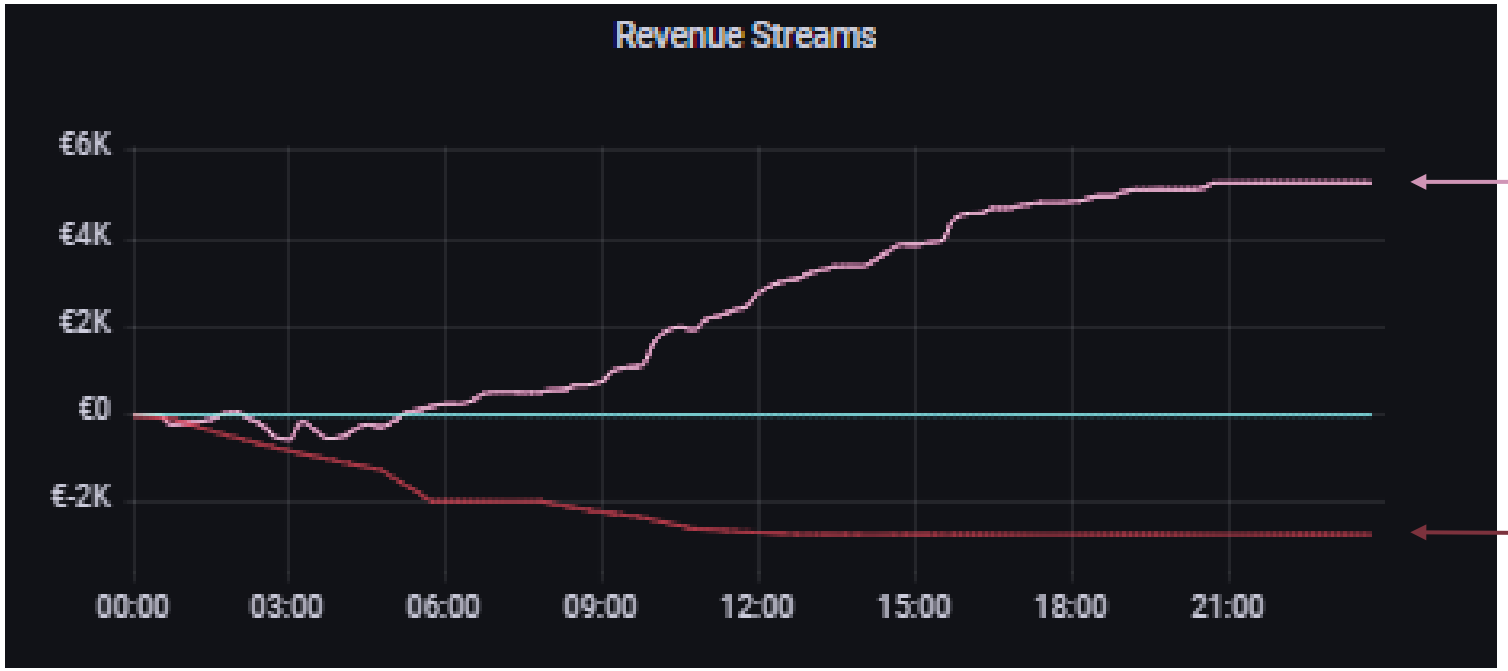
Turning costs into profit



Profit of +27EUR/MWh
by x-market optimisation

Cost of -14EUR/MWh
by DA charging

Exemplary day of a 20 MW, 4h thermal storage asset in summer 2025 with flat heat demand profile

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Simulation of 20 MW thermal storage

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20 MW, 4h thermal storage asset from July to October 2024

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X-market optimisation of TES as an enabler to decarbonise industrial heat

Electricity isn't just a fixed cost – short-term markets provide arbitrage opportunities cutting power expenses and even generate revenue by providing balancing services to the grid

Enspired's approach enables the business case of TESS – by optimising it on all available markets (WS + balancing markets) , we make it more price competitive than gas-fuelled boilers

Charging at the best possible price – Our optimisation of thermal storage leverages price spreads on DA + ID markets and generates revenue by providing charging capacity on aFRR markets

The numbers speak for itself – a live simulation of a 20 MW, 4 hour system in Germany, show that on some days we cut the charging costs while on others wen could generate a profit

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Heat in the Market: Designing Market Mechanisms for Thermal Participation

András Vinkovits

Executive Chairman at Energiabörze

ENERGIABÖRZE

Heat in the Market

Designing Market Mechanisms for Thermal Participation

András Vinkovits, Energiabörze

Energiabörze Group

25+ YEARS EXPERIENCE

50+ PROFESSIONAL SPECIALIST

600+ MW MANAGED PORTFOLIO

14 OWN POWER PLANTS

57 MEUR ANNUAL REVENUE

190+ SATISFIED CUSTOMER

200+ PARTER POWER PLANT

Private, entrepreneur = independent to innovate

Energiabörze Group

- Gas engines
  Biogas engines
  Gas turbines
- Market PVs
  METÁR (CFD) PVs
  KÁT (FID) PVs
- Electric boilers
  Storages
  METÁROLÓ
- Scheduling
- aFRR control
- Full scale trading
  Balance Group
- Own IT and business development
- Complete commercial services for power plants
- PPAs

„We generate and regulate energy to ensure stability and balance for ourselves and for our partners through our innovative solutions.”

How market structures are adapting to integrate TES

In renewable systems energy efficiency has become less important, with a greater focus on achieving and maintaining momentum: for load shifting the key assets are storages

Hot water storage

- Cheap, but limited
- District- or building heating
- Domestic hot water

Steam storage – Heatcube

- In CHPs learn the value is in annual utilization. Steam supply has it
- Large scale, all year-round heat consumption is industrial steam
- Long lasting, durable technology needed
- Steam flexibility can support energy system balancing and decarbonization

BESS

- 8-10.000 cycle limits and the high degradation are clear drawbacks
- Power-to-power

Lessons learnt as TES investor/operator

- In Central East Europe you must be competitive. Being green is second priority
- Most important steam source is natural gas – we have to beat/match is
- EUA projections and network tariffs are equally important. e.g. HU mid-voltage tariff is 55-60 EUR/MWh, while gas 3 EUR/MWh
- Heat supply, heat storage has a long-term counterparty exposure – customer side BESS as well, but easier to relocate

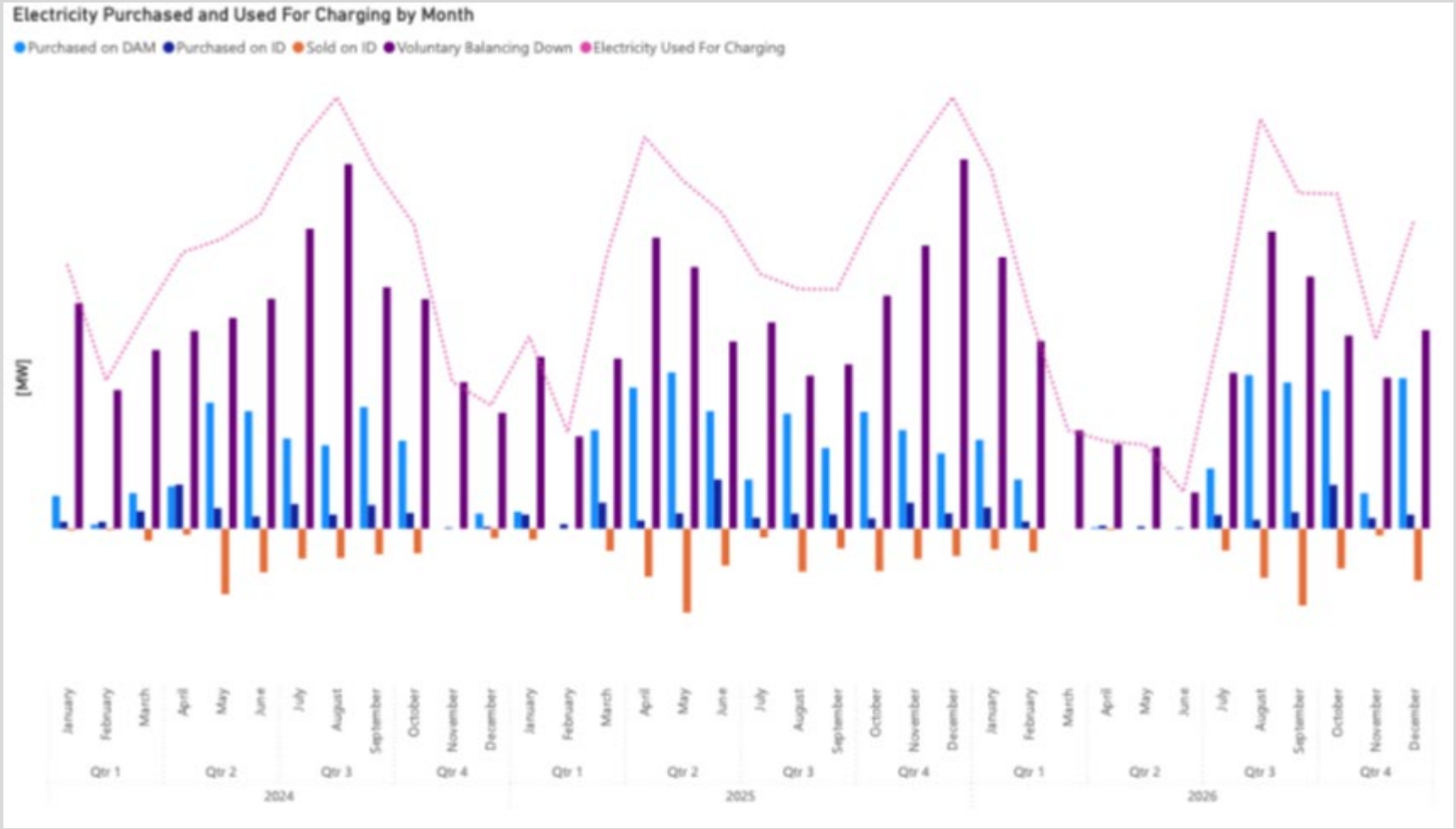
Market access, regulations, and barriers

- DSOs are highest investment risks. Hungary had appx 10 GW main large scale power production in 2010. 8 GW PV has been built and 5-6 GW started access process. Electrification bombs up consumption side as well.
- Wide range, and relatively easy to access markets.
  - Market coupling and XBID connected European Day-Ahead and Intraday markets.
  - Picasso expected Q4 2026. It will join aFRR as well.
  - Well developed aFRR capacity market – expected 1-2 GM BESS will destroy it
- Optimization became extremely complex. We need to change business logic 4-6 times a year

Energy markets are like telco in late 1990's.
Mobiles (renewables, storages) are already here. Everyone is only guessing how to use it, would it vanish land-line (large-scale conventional)?
What about Grid?

Insights of pilot projects shape confidence in the role of TES

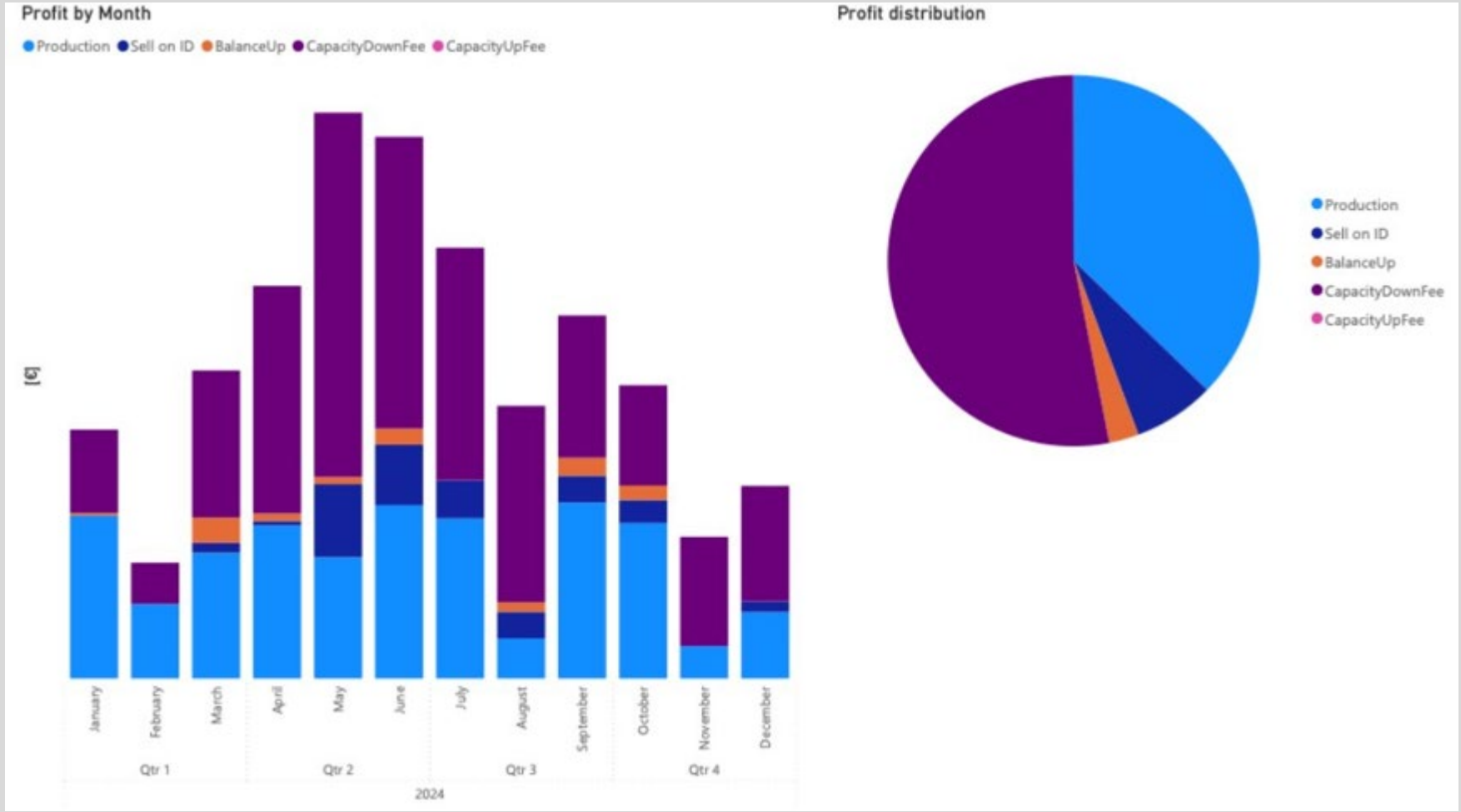
Simulated source of Heatcube production



Heatcube simulation

- aFRR accreditation is already achieved
- Due to price structure capacity fee drives in 2024-25-26.
- Flexible assets should jump on imbalances – not only aFRR but Intraday
- Key challenge is to merge close to real-time production decisions with steam customer's long term price hedging requirement

Heatcube retrospective model of 2024



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The on-demand version will be availble here