

Beyond Batteries: The Missing Piece of Data Center Energy Storage

Jorge Salgado Beceiro
Research Manager
SINTEF Energy Research

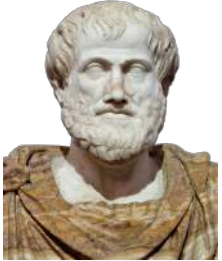


DATACENTER
FORUM

Copenhagen
24 September 2026
Radisson Blu Scandinavia Hotel



Global Energy Consumption



Enérgeia

En ("in")

Ergon ("work")

"Work in"



$$1 \text{ N} = 1 \text{ kg} \frac{\text{m}}{\text{s}^2}$$



**Richard
Feynman**

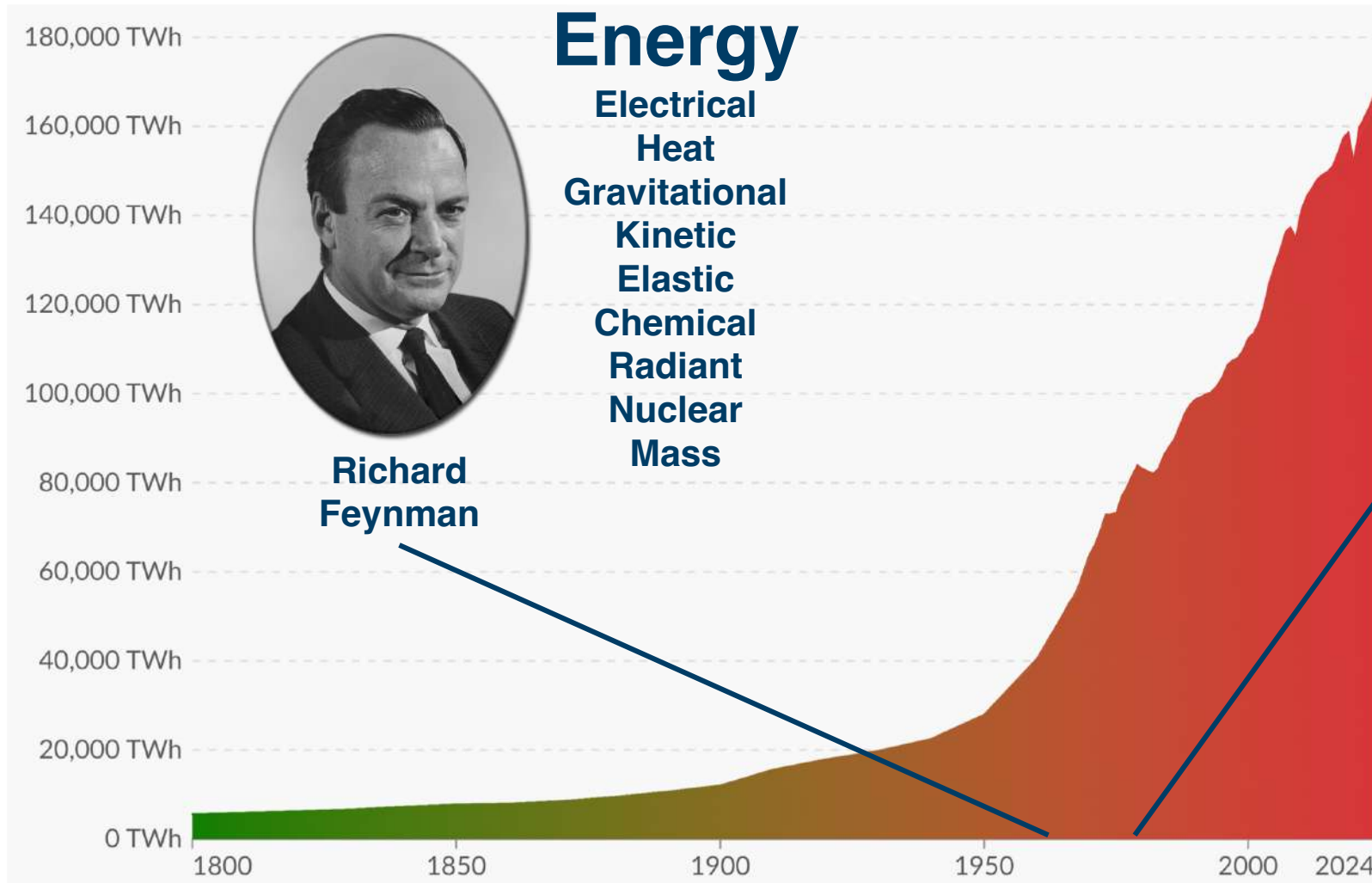
Energy

Electrical
Heat
Gravitational
Kinetic
Elastic
Chemical
Radiant
Nuclear
Mass



**Robert
Ayres**

Energy
is the world's
only truly
currency



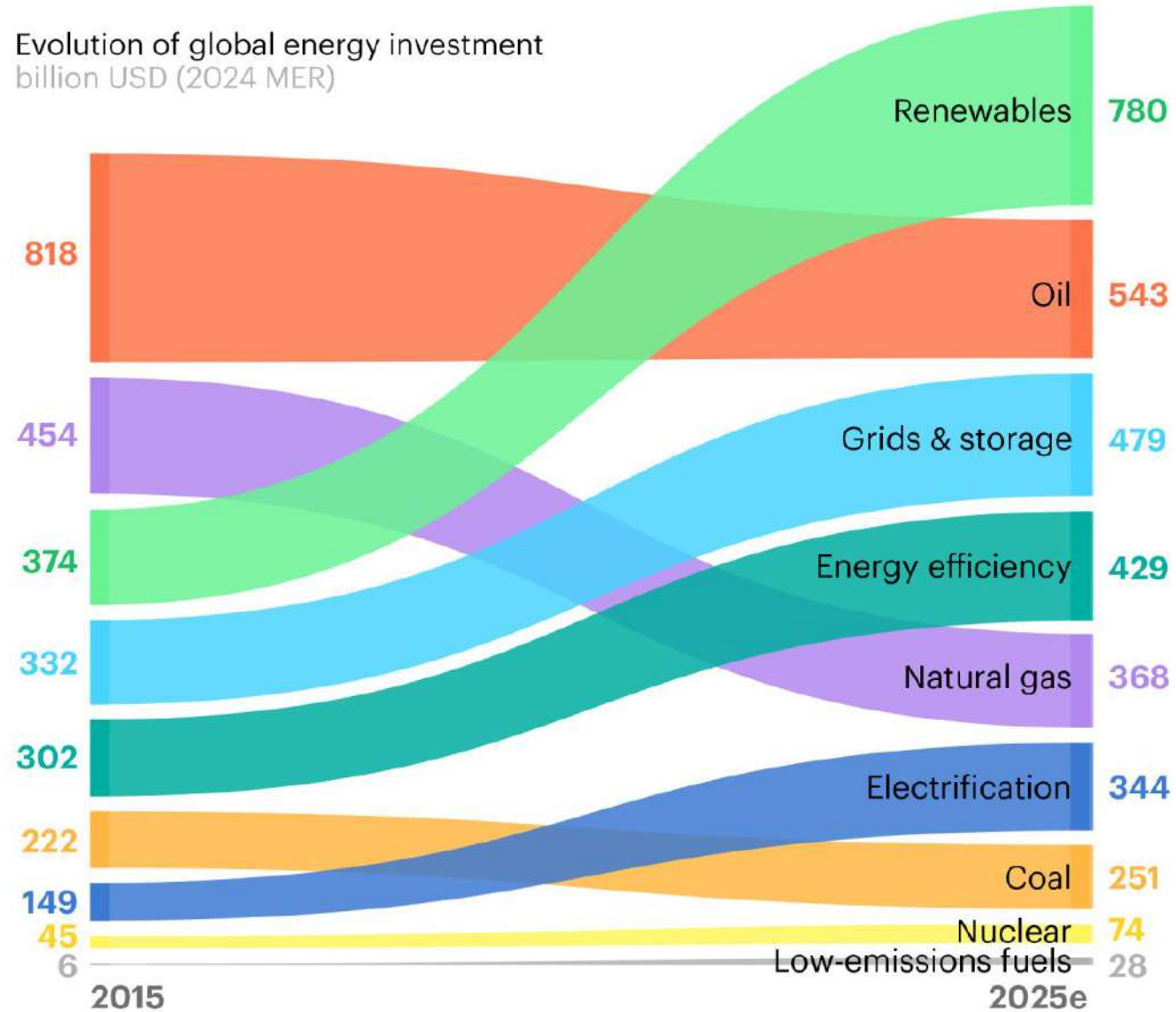




The world's energy investment landscape is changing

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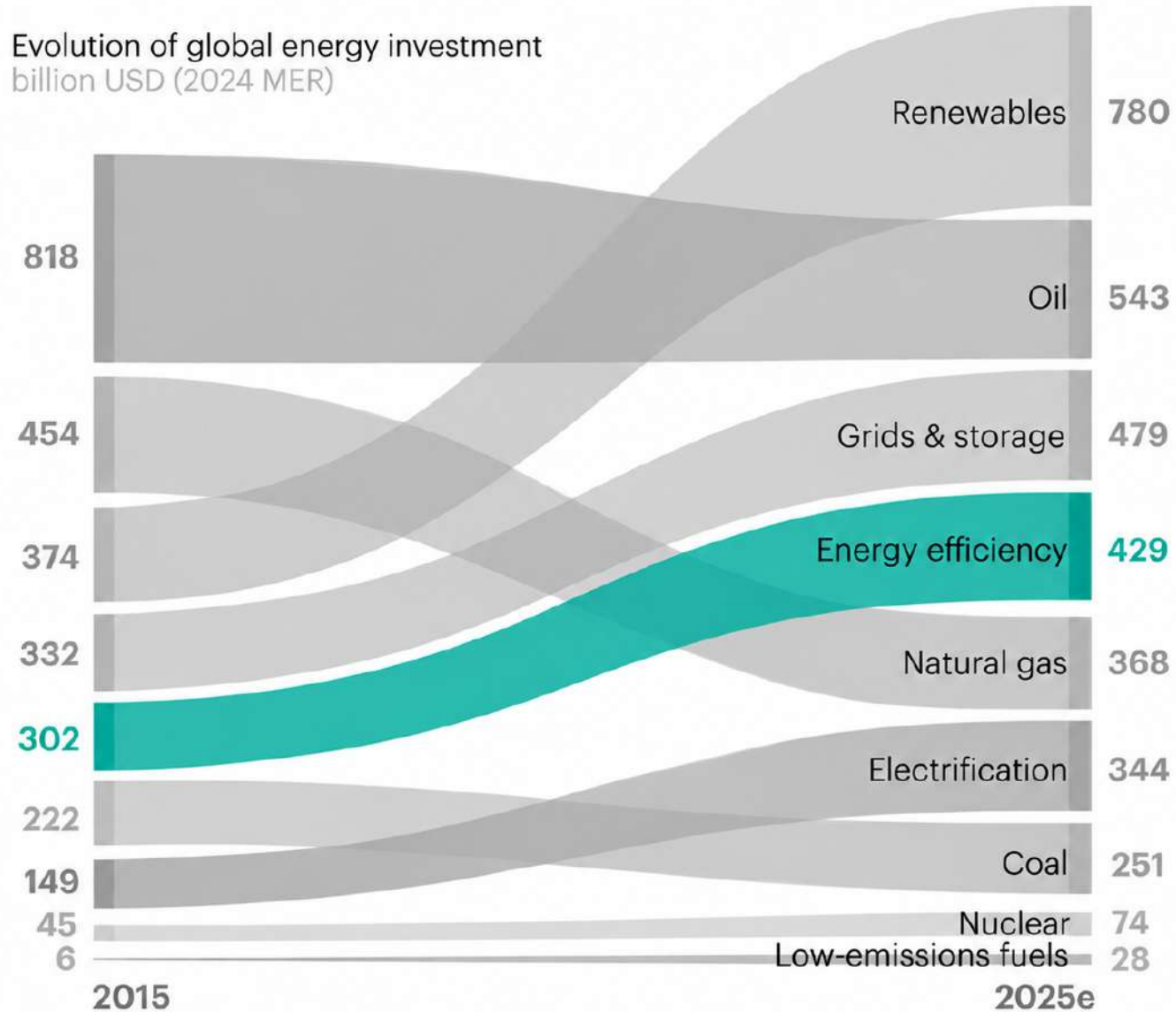
Evolution of global energy investment
billion USD (2024 MER)



The world's energy investment landscape is changing

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Evolution of global energy investment
billion USD (2024 MER)



Energy Efficiency

5.5 M



15 MWh per year



20 TWh

1.3 M Households

(2.6M total in Norway)

Energy Efficiency



Energy Efficiency



Energy Efficiency

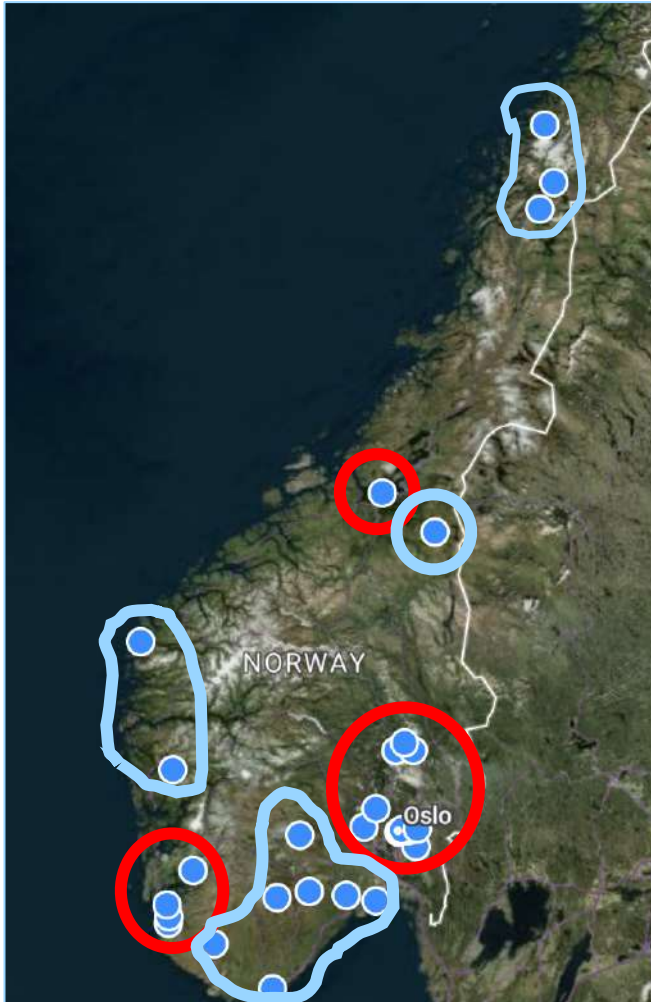
- Waste Heat = Untapped Value (and Regulatory Pressure).



Mandatory to assess, plan,
and report use of waste heat



Energy Efficiency



Remote:
Cooling and renewables
integration

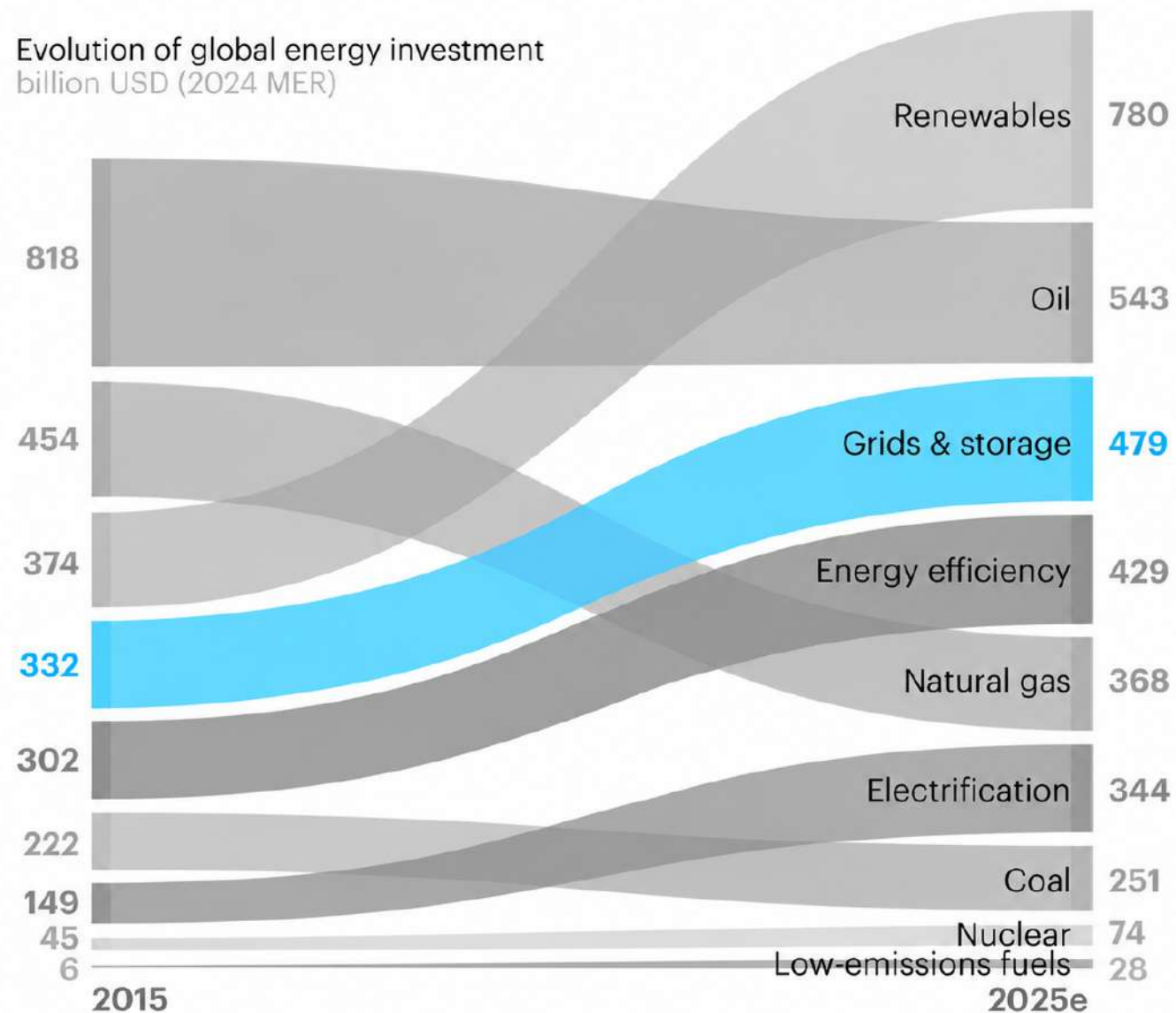


Metropolitan/Industrial:
Waste heat reuse

The world's energy investment landscape is changing

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Grids & Storage



Grids & Storage

Backup (UPS)

- Dominant use today
- Lithium-ion, standard across the industry



Peak Shaving / PV Dispatch

- Emerging use case
- Mostly pilot-scale deployments



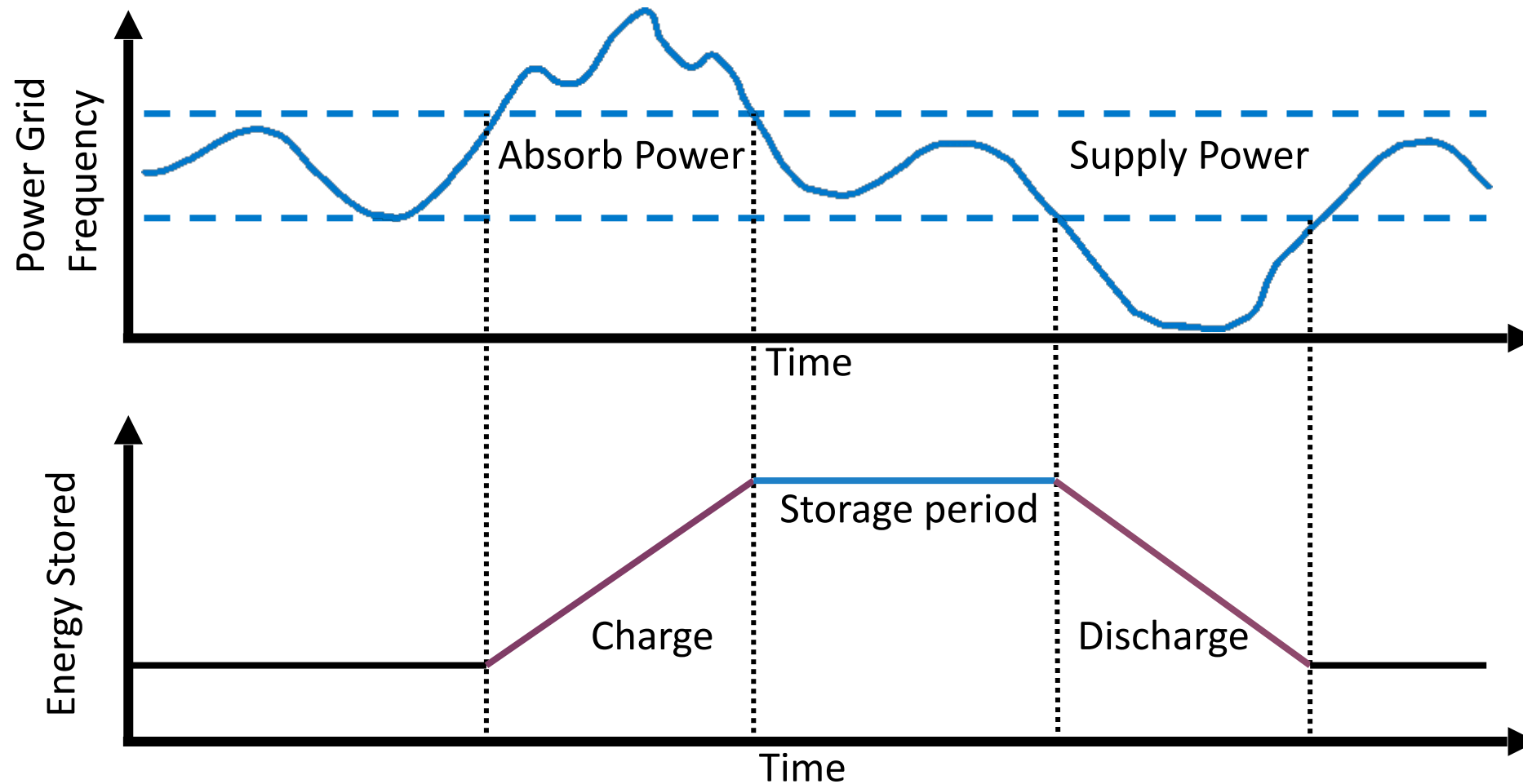
Grid Services (Flexibility)

- Rare in practice
- Considered for few data centers in construction in Norway



Grids & Storage

- More Profitable → Enable participation in reserve markets.



Grids & Storage — 2025 Update

- Storage enabling participation in reserve markets.

Market	Response time	Duration	Bid size	Av. profit (updated)	Notes
FFR-Profil	1.3s	5s	1 to 50 MW	119 NOK/MW/h	Only up-regulation. (Apr to Oct. 1350 h)
FFR-Flex	1.3s	5s	5 MW	390 NOK/MW/h	Only up-regulation. (Apr to Oct. 400 h)
FCR-D opp	7.5s	15m	0.1 MW	235 NOK/MW/h	Only up-regulation (May to Sep.)
FCR-N	3m	15m	0.1 MW	290 NOK/MW/h	Up- and down-regulation
aFRR opp	5m	60m	1 MW	103 NOK/MW/h	Only up-regulation
aFRR ned	5m	60m	1 MW	88 NOK/MW/h	Only down-regulation
mFRR opp	15m	60m	5/10 MW	57 NOK/MW/h	Only up-regulation
mFRR ned	15m	60m	5/10 MW	95 NOK/MW/h	Only down-regulation

Up-regulation: Discharge to grid to increase frequency

Down-regulation: Charge from grid to reduce frequency

Grids & Storage → Cooling

~40%

Grids & Storage →

FREE COOLING

- **Airside:** direct and indirect economizers
- **Waterside:** fjord or sea water at about 8 °C via heat exchanger
- **Climate:** compressors idle most of the year, very low PUE
- **But:** the cold time is set by weather (day/week/season), not by the load peak



Nordic DC Cooling

MECHANICAL REFRIGERATION IN THE LOOP

- **Air cooling (AC):** room, row or rack CRAC/CRAH with aisle containment, up to about 10-20 kW/rack
- **Liquid cooling (LC):** rear-door heat exchangers, direct-to-chip, immersion, spray, above 20-50 kW/rack
- **Hybrid (HC):** combinations matched to component heat flux
- **And:** the chiller is sized for the peak, not the average
- **Working fluid:** synthetic HFC or natural refrigerants (CO₂, ammonia)

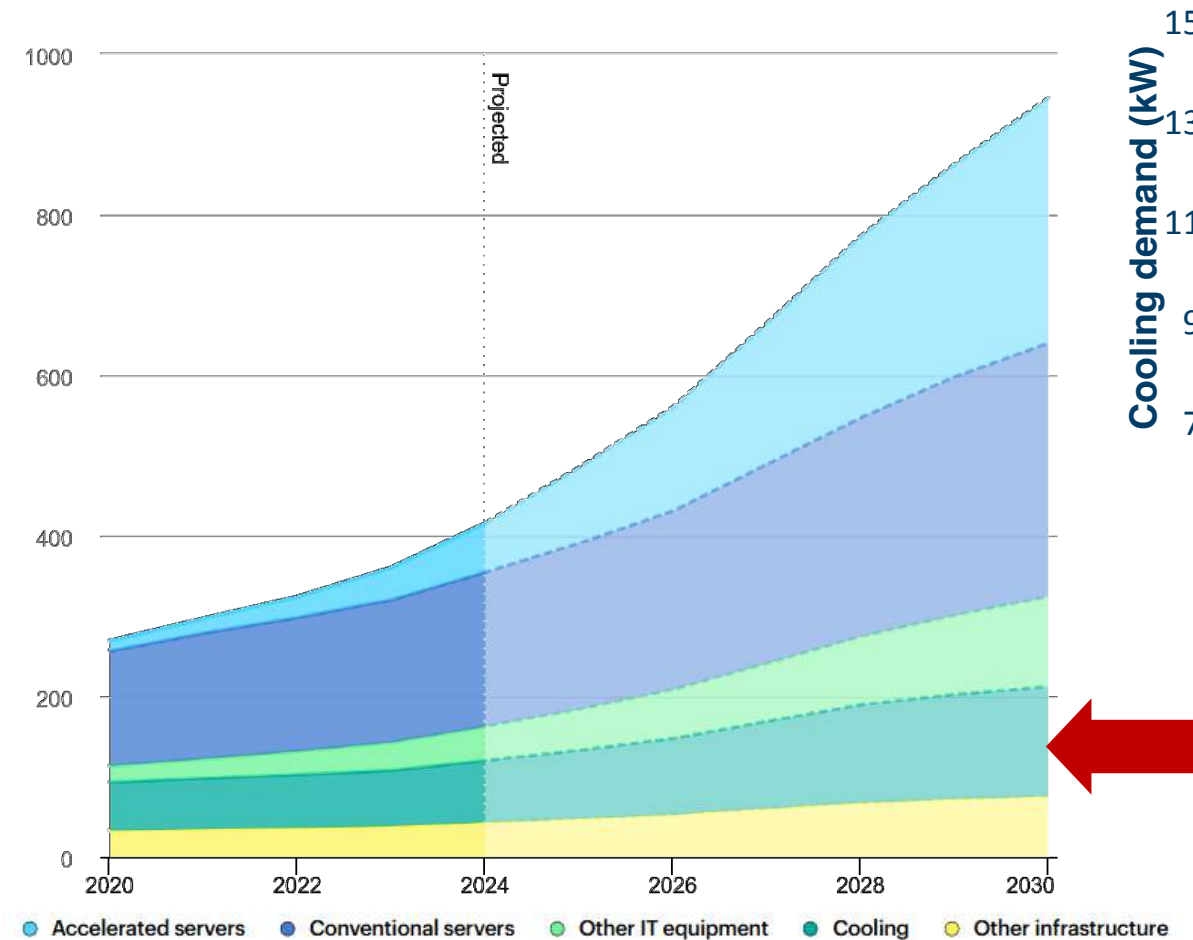


Grids & Storage → Cooling

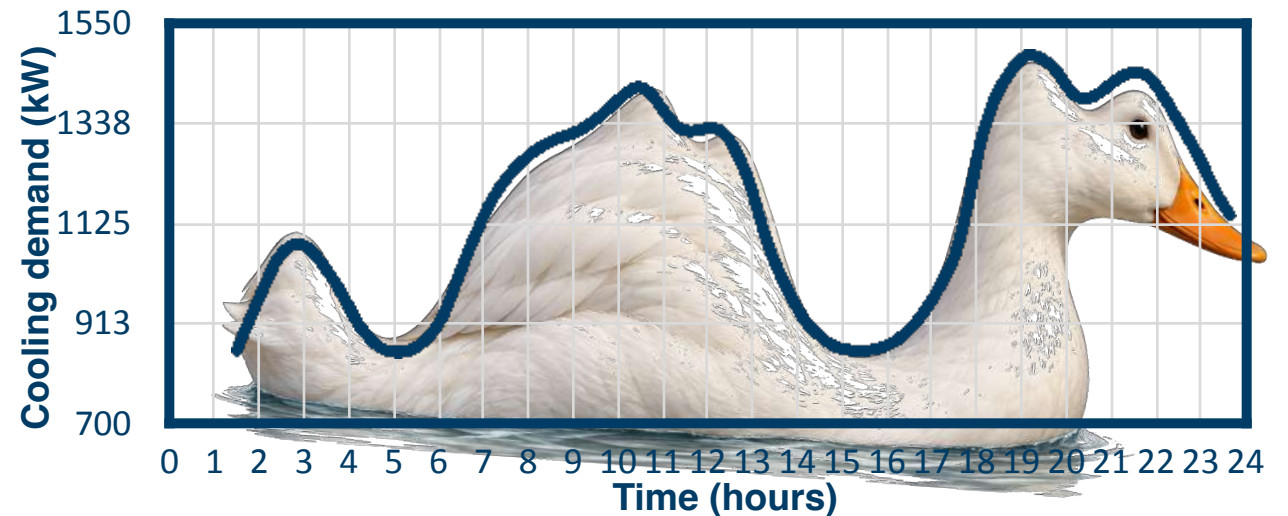


Grids & Storage: Cooling

- Cooling = Big Load (up to 40% of electricity on average).

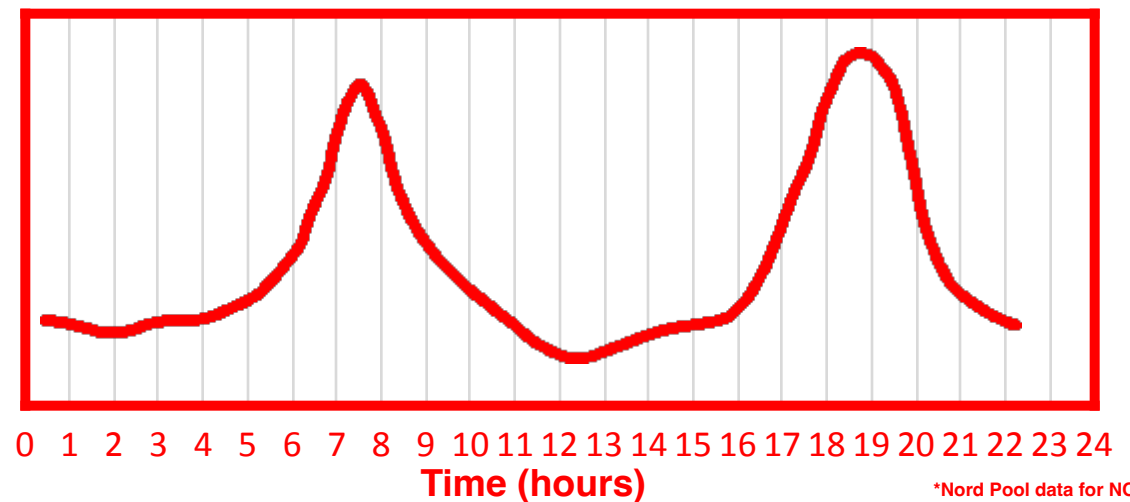


International Energy Agency (2025). *Energy use in data centres and artificial intelligence*.



0,69

0,475



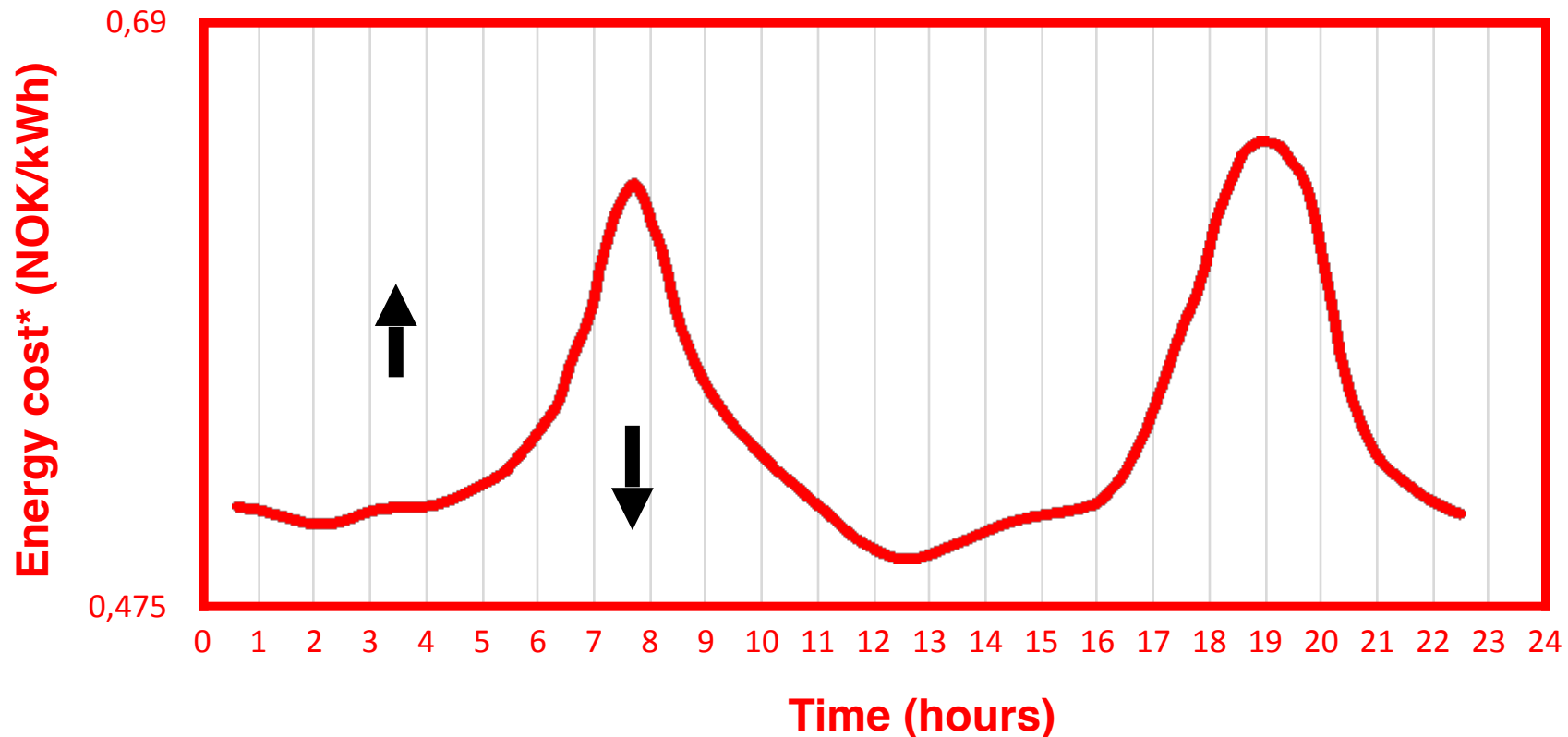
Energy cost* (NOK/kWh)

*Nord Pool data for NO1 (17/03/2025)

Grids & Storage: Cold Storage

- Cheaper → Shift cooling loads to off-peak hours.

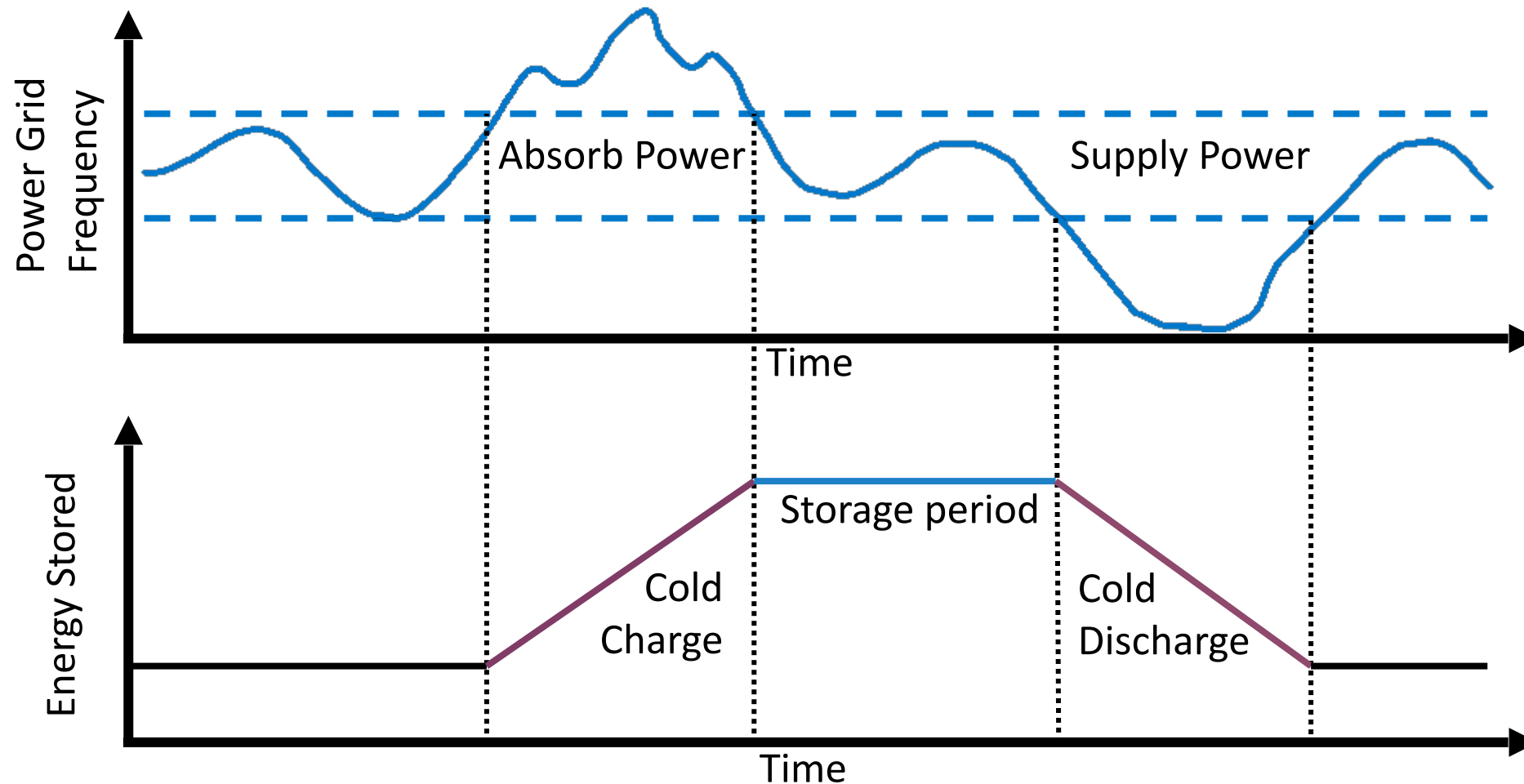
Storage Schedule



*Nord Pool data for NO1 (17/03/2025)

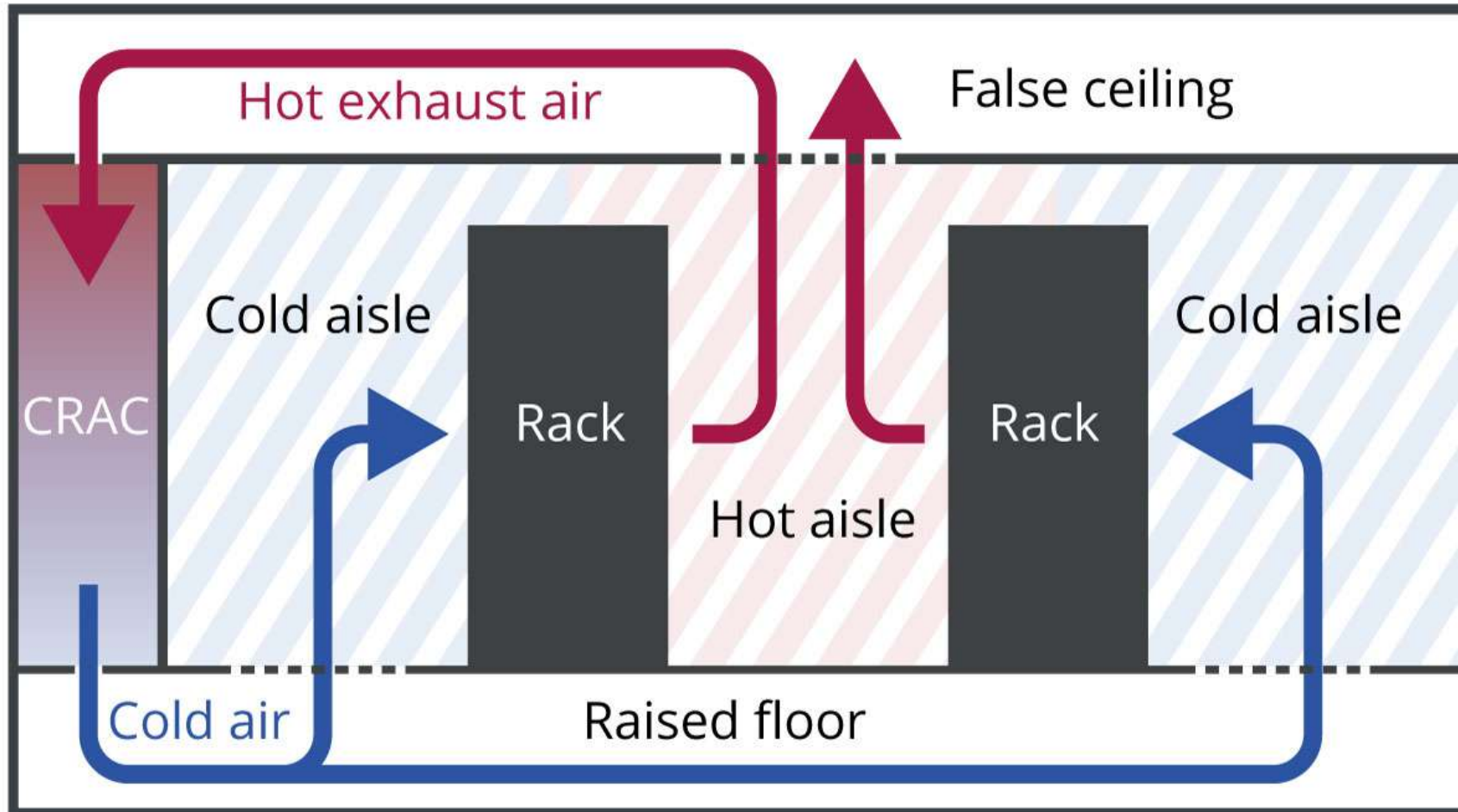
Grids & Storage: Cold Storage

- Enable participation in reserve markets.

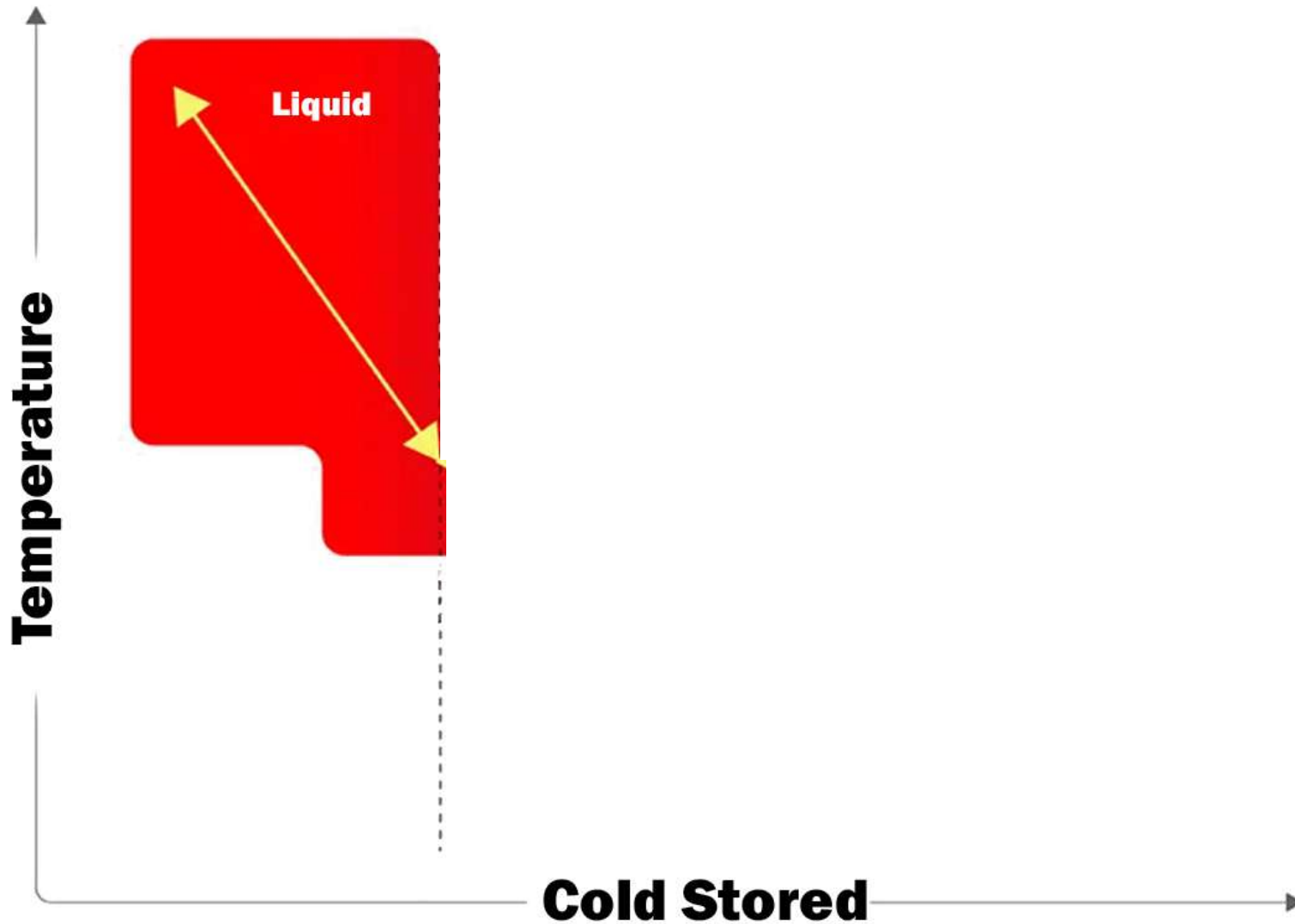


Grids & Storage: Cold Storage

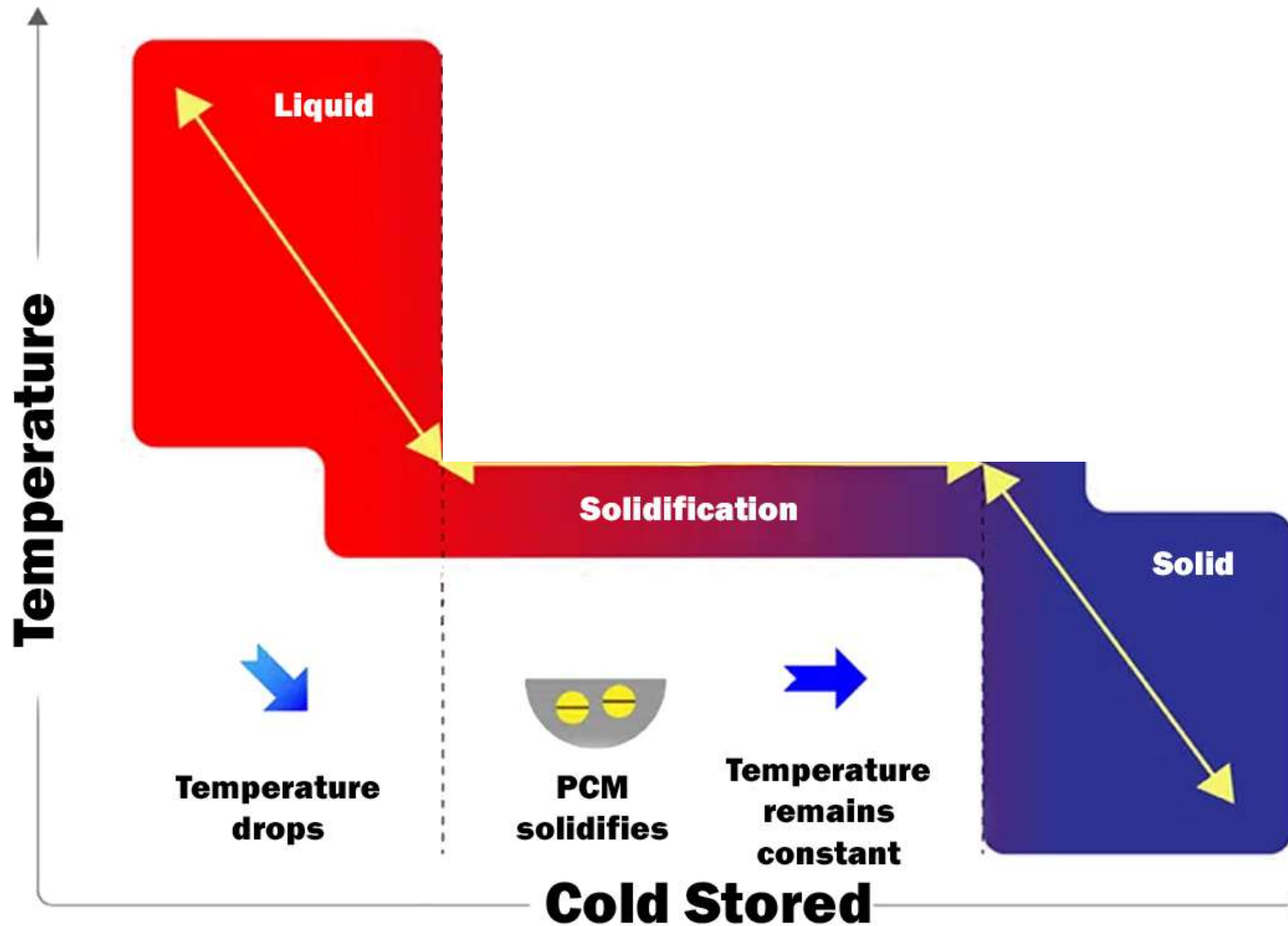
Cooling system:



Grids & Storage: Cold Storage



Grids & Storage: Cold Storage

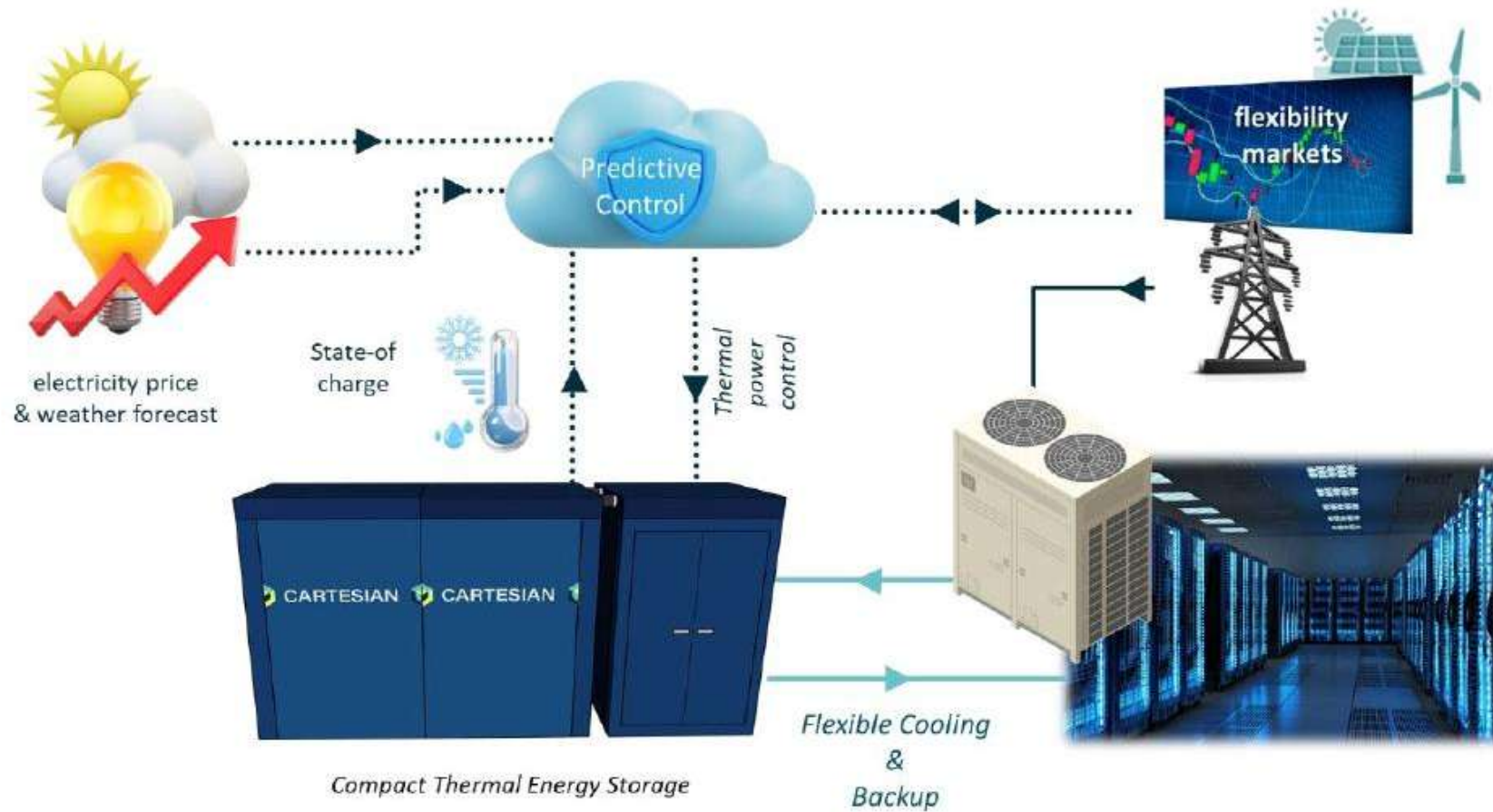


Real-World Case: La-Flex at DTU Risø

- A cold thermal storage (TES) unit installed at a data center on DTU Risø Campus, Denmark.
- PCM thermal storage unit from Cartesian
- Goal: validate cold storage for data center cooling flexibility and reserve-market participation.

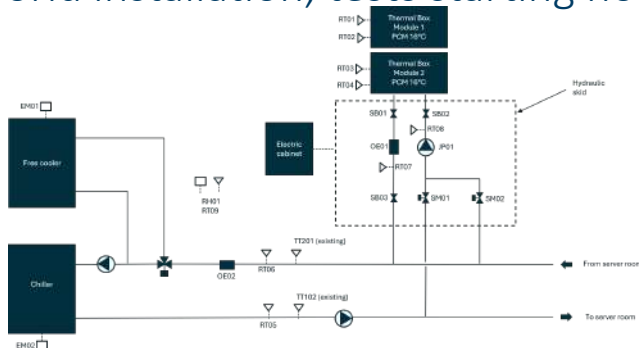


Real-World Case: La-Flex at DTU Risø

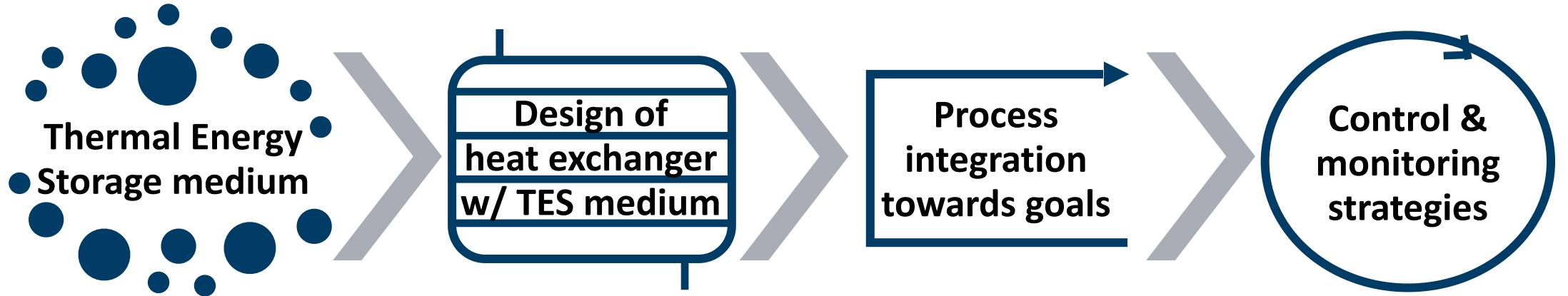


Real-World Case: La-Flex at DTU Risø

- Cold storage (PCM, ~16°C melting point), sized for the data center's cooling load.
 - Energy efficiency: maximize free cooling in spring/fall; improve COP by producing cooling at night.
 - Operations: reduce on/off cycling of the chiller during part-load conditions.
 - Added revenue: quantify additional revenue from participation in flexibility markets.
- Recently commissioned — an early, real-world installation, tests starting now.



Thermal Storage → Research Trends



Lower CAPEX

Durability

Low CRM use

Sustainability

Safety

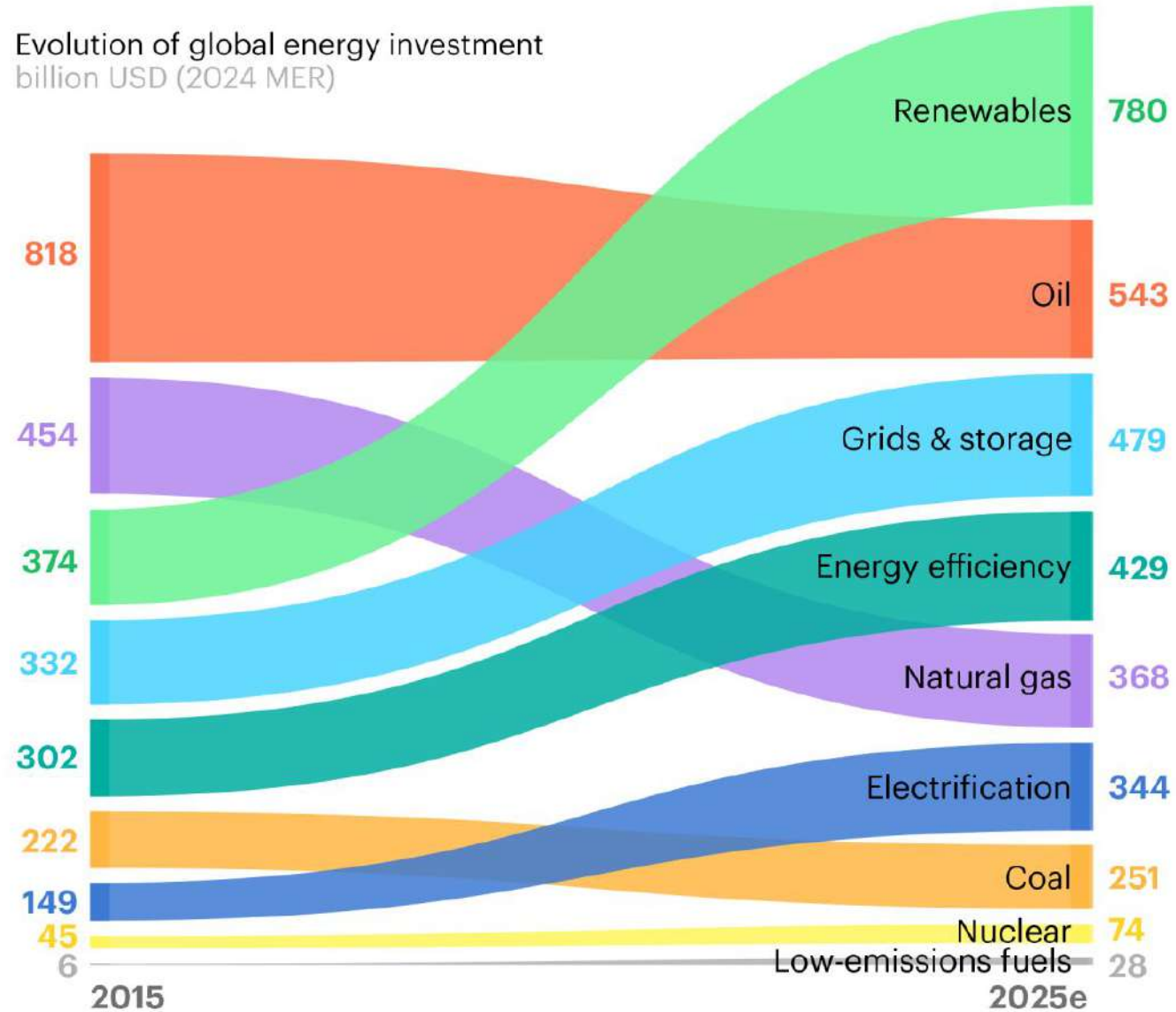
Accurate Control

Lower OPEX

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Acknowledgments:
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CETP La-Flex



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