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Long-Duration Energy Storage for power system and industrial heat decarbonization. Technology assessment of power-to-heat service applications.

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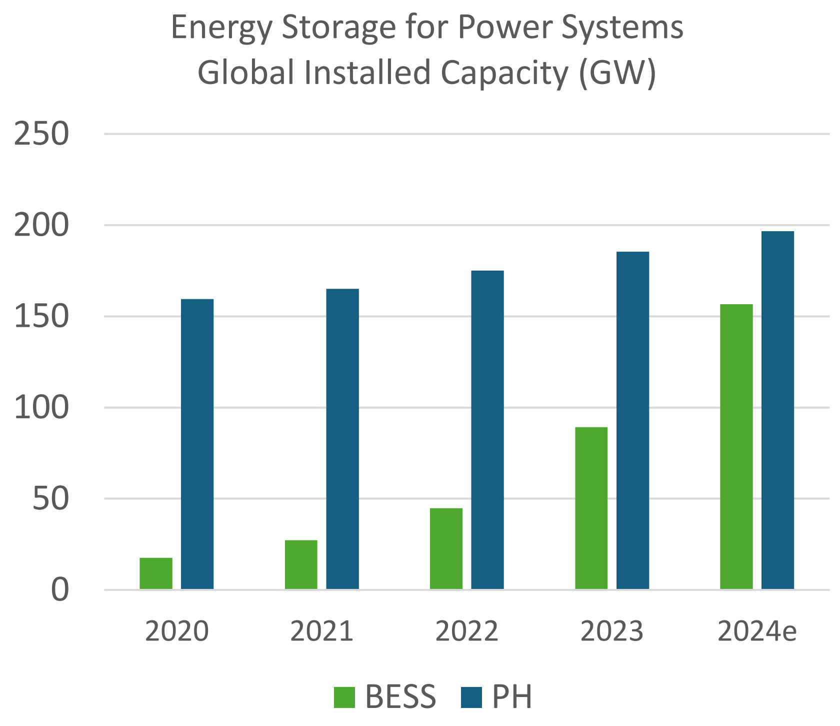
Energy Storage Capacity for Power Systems

- ❑ Global Electricity Demand 2024: ~28,000 TWh
- ❑ Energy Storage Global Installed Capacity 2024: **360 GW** | 10.400 GWh **(~0.03% of demand)**



- ❑ In terms of power (tot 360 GW):
  PH 197 GW (55%), **BESS 157 GW (44%)**, TES&ot. 6 GW (1%)
  BESS capacity growing exponentially (**in 2025 BESS > PH**)

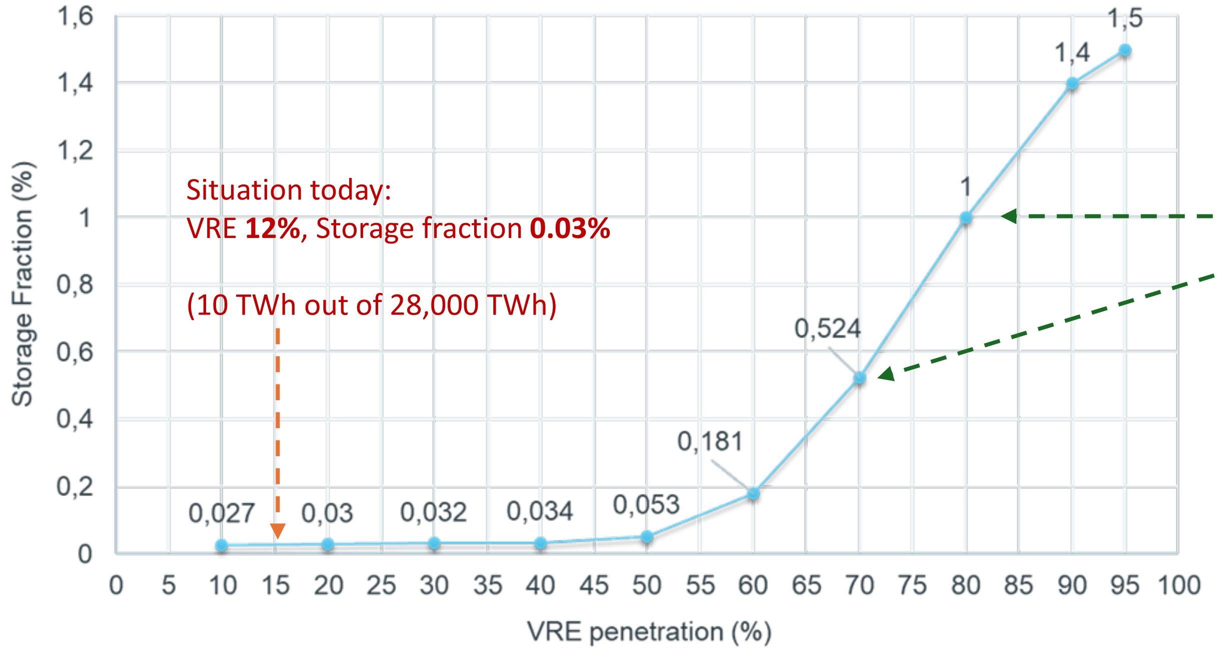
- ❑ In terms of energy (tot 10.400 GWh), PH largely dominant:
  PH: 96%, BESS: 4%, TES: 0,2%

- ❑ Today's ES Energy/Power Ratio (global average):
  PH: >50 GWh/GW (50 h "duration")
  BESS: 2,5 GWh/GW (2,5 h "duration")

ES and VRE Penetration in Power Systems

- 2022/2023 Global Electricity Generation Mix (IEA, IRENA)
  VRE - Variable Renewable Energy (Wind+Solar) Penetration: **12% (3,400 TWh)**

Energy Storage Needs vs. VRE Penetration



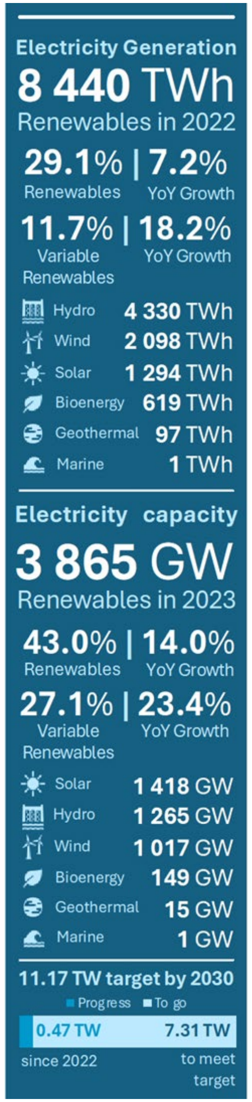
Typical Zero-Carbon Scenario:
VRE **80%** → Storage fraction **1.0%**
VRE **70%** → Storage fraction **0.5%**

e.g. out of 28,000 TWh:

VRE (70%) ~20,000 TWh → x6

Storage (0,5%) ~100 TWh → x10

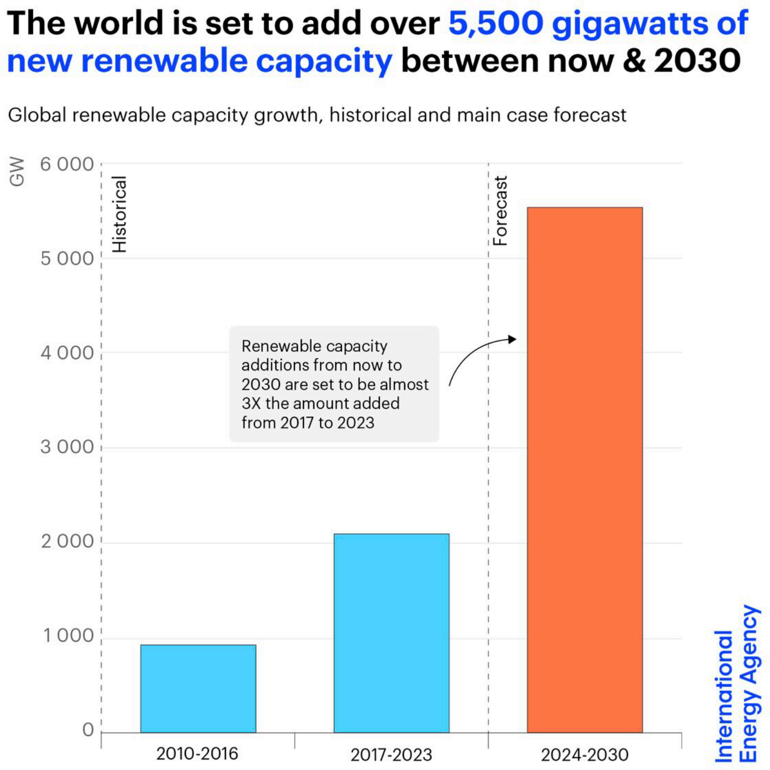
Impossible with BESS only, needs for LDES

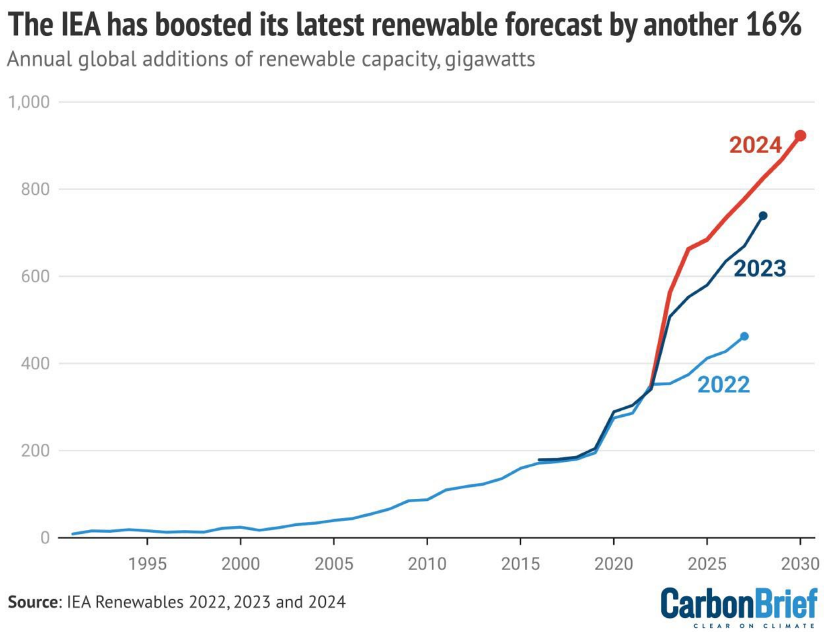


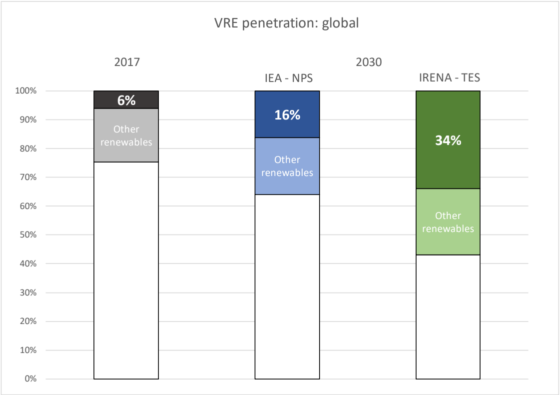
Modeling smulation results for the EU power system
Optimizations are possibile

2030 Perspective: A Global Race for (V)RES and (B)ESS

- ❑ Running towards a 100%-RES power system (RES competitiveness is the new driver)







30%÷35% VRE Penetration Expected in 2030 (Worldwide)

→ VRE: **x3** ES: **x6**

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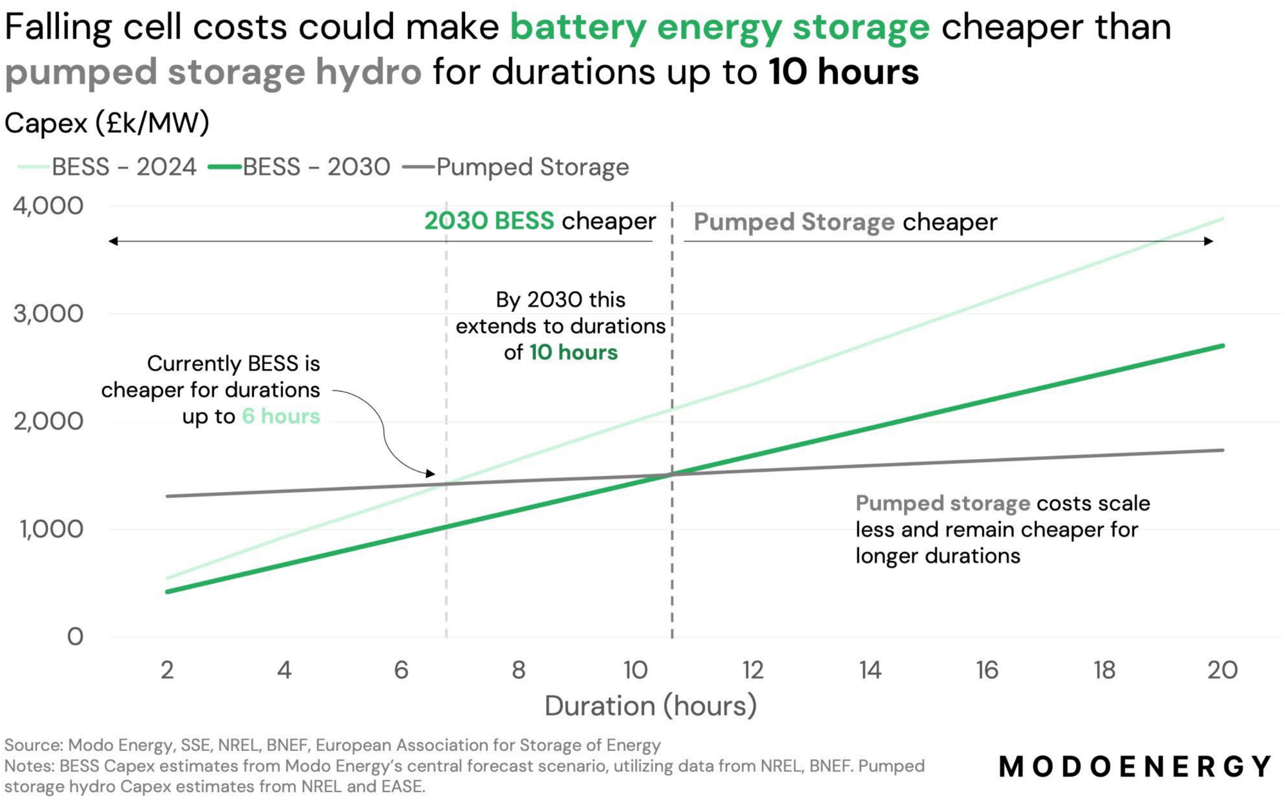
ES Technology Mix for Future Power Systems

- ❑ Pumped Hydro Global Potential (Huge. Deployable?): 820,000 sites | **86,000 TWh**



- ❑ **BESS** could conveniently cover the needs for **Short Duration Energy Storage** (up to 10 GWh/GW)

- ❑ **PH** has to remain dominant and cover the needs for **Long Duration Energy Storage**

- ❑ **Heat decarbonization through VRE electrification?** Cross-sectoral benefits of **Power-to-Heat (eTES)** and Power-to-X (H2, e-fuels, etc.) energy storage solutions.

The Concept of Electric Thermal Energy Storage (ETES)

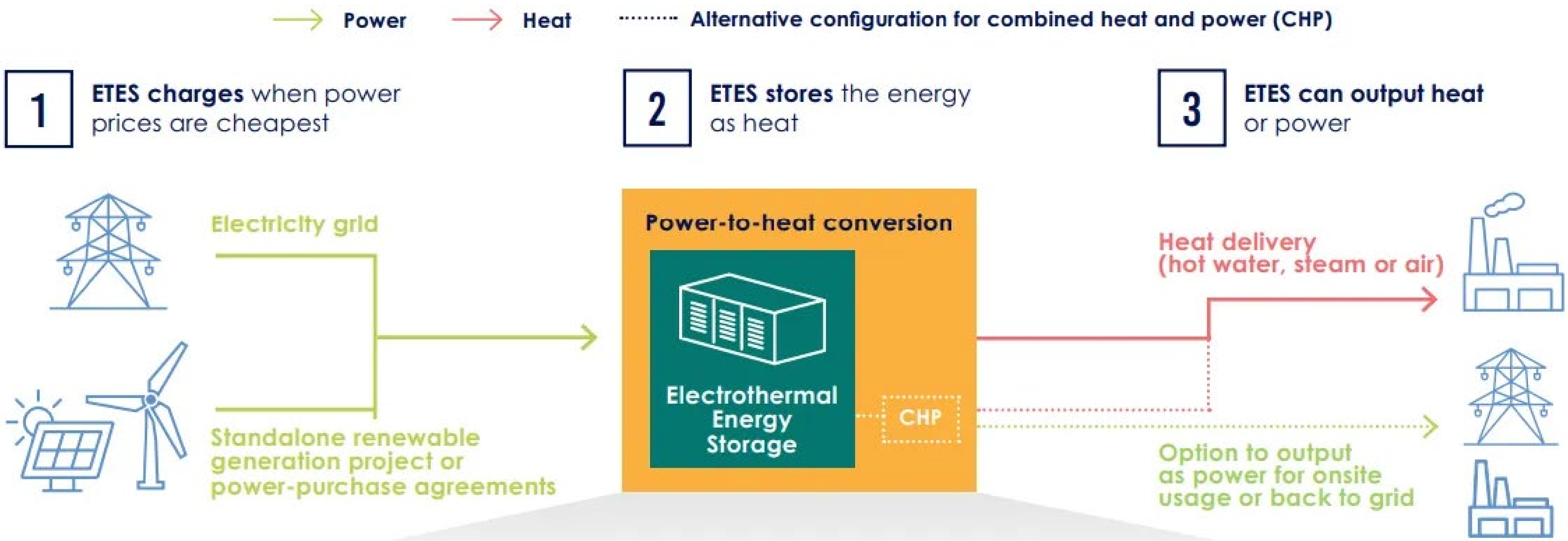
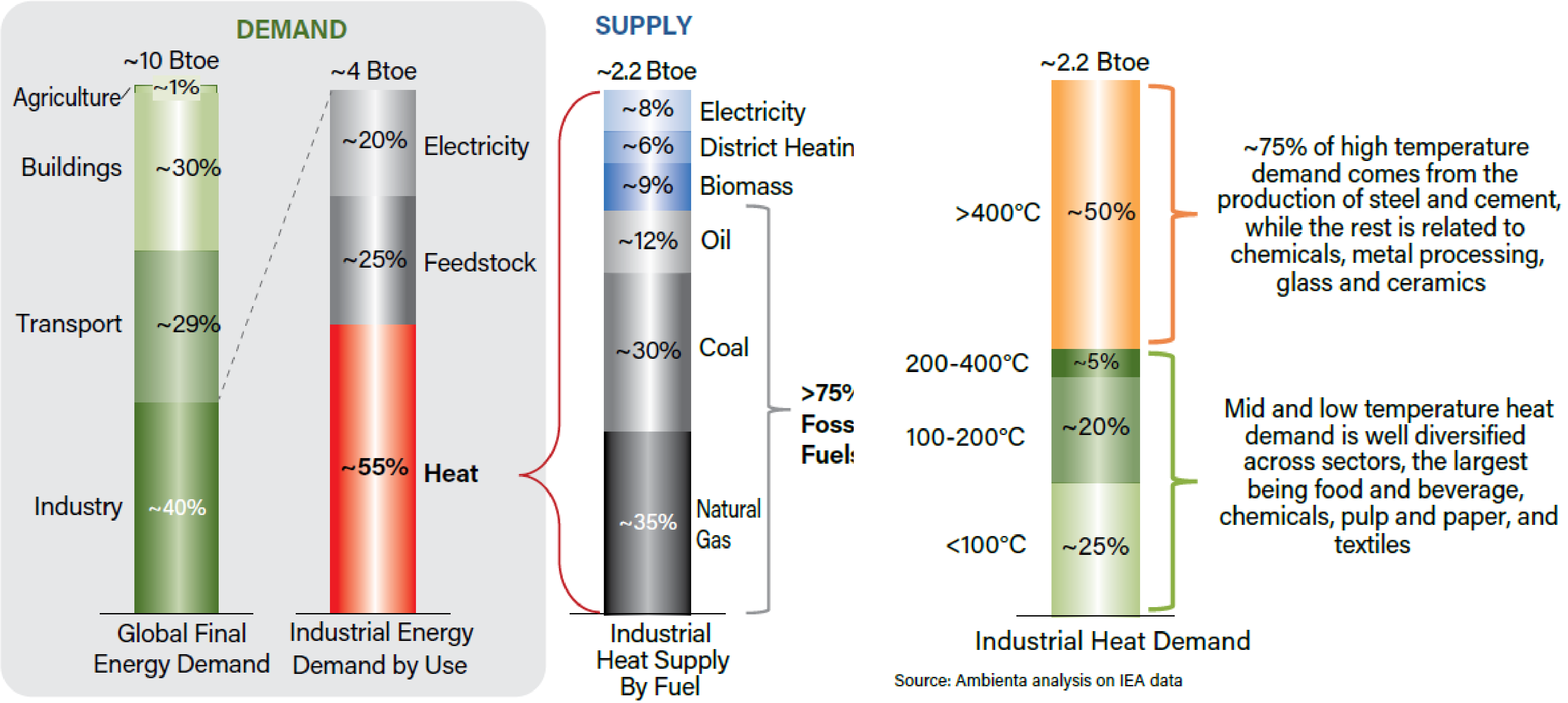


Image credit: Systemiq / Breakthrough Energy

Industrial Heat Demand and Supply



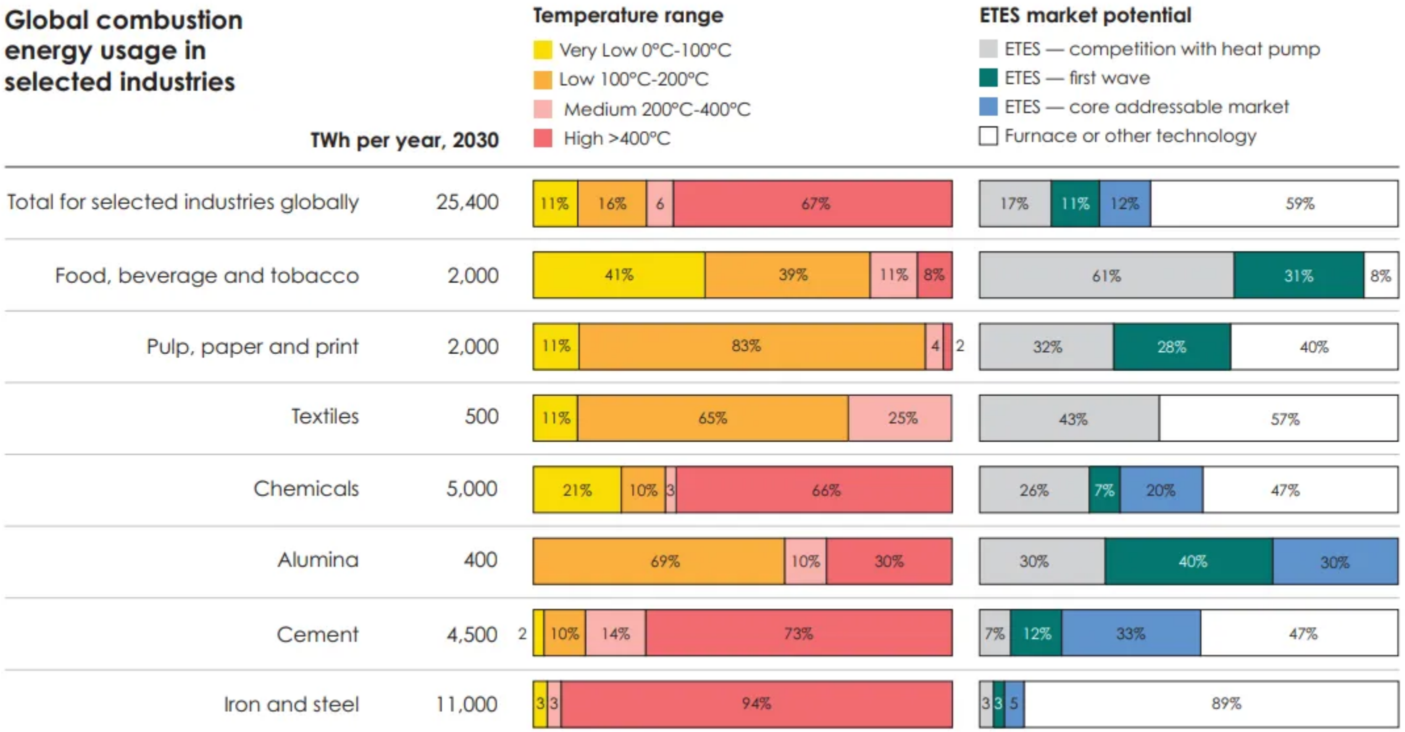
Source: Ambienta analysis on IEA data

Source: Ambienta analysis on IEA and McKinsey Data

The huge impact of the Industrial heat:

- **>20%** of global final energy demand
- **>10%** of the world's CO2 emissions

ETES Application for Industrial Heat Decarbonization



Note: Only considers energy usage from fuel combustion, not emissions from process, power sector and transportation energy consumption.
Source: UNFCCC data set (2021), except for Australia (2019); International Aluminum Institute; World Steel Association; Eurostat; EuraTEX; USGS; Petrochemical Europe; EU heat profile is derived from EU Joint Research Center; US heat profile is derived from Decarbonizing Low-Temperature Industrial Heat in the U.S., Energy Innovations, 2023

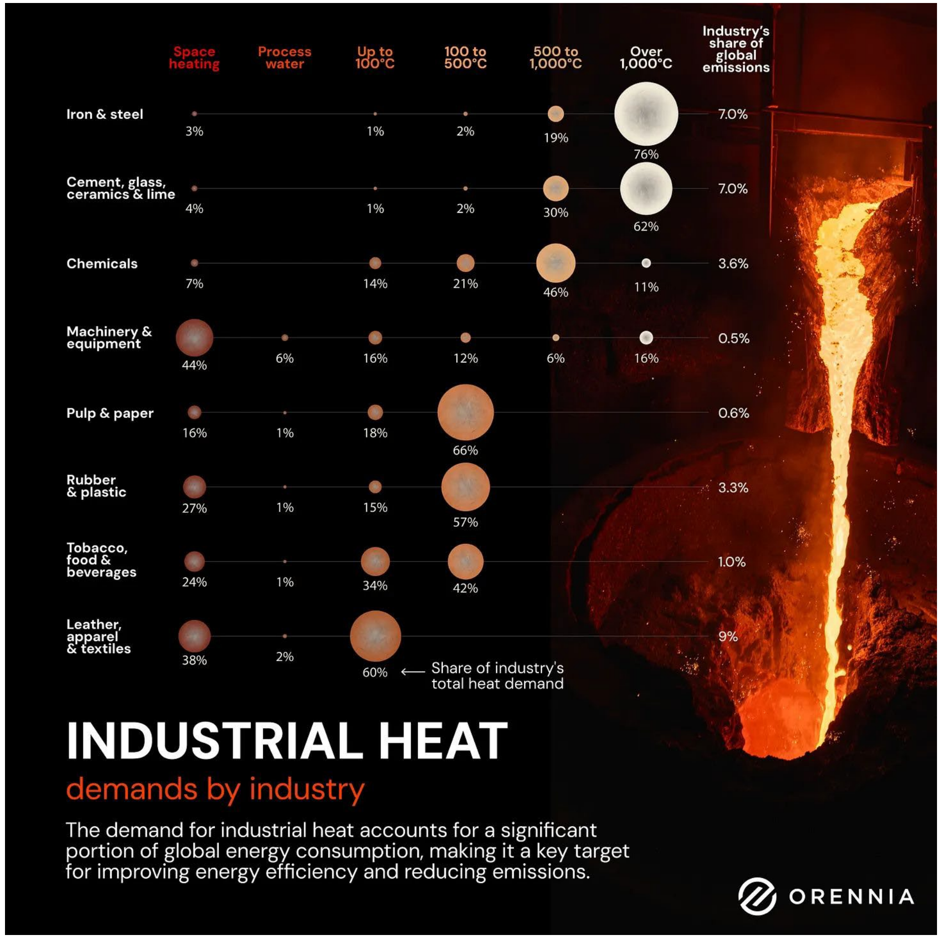


Image credit: Systemiq / Breakthrough Energy

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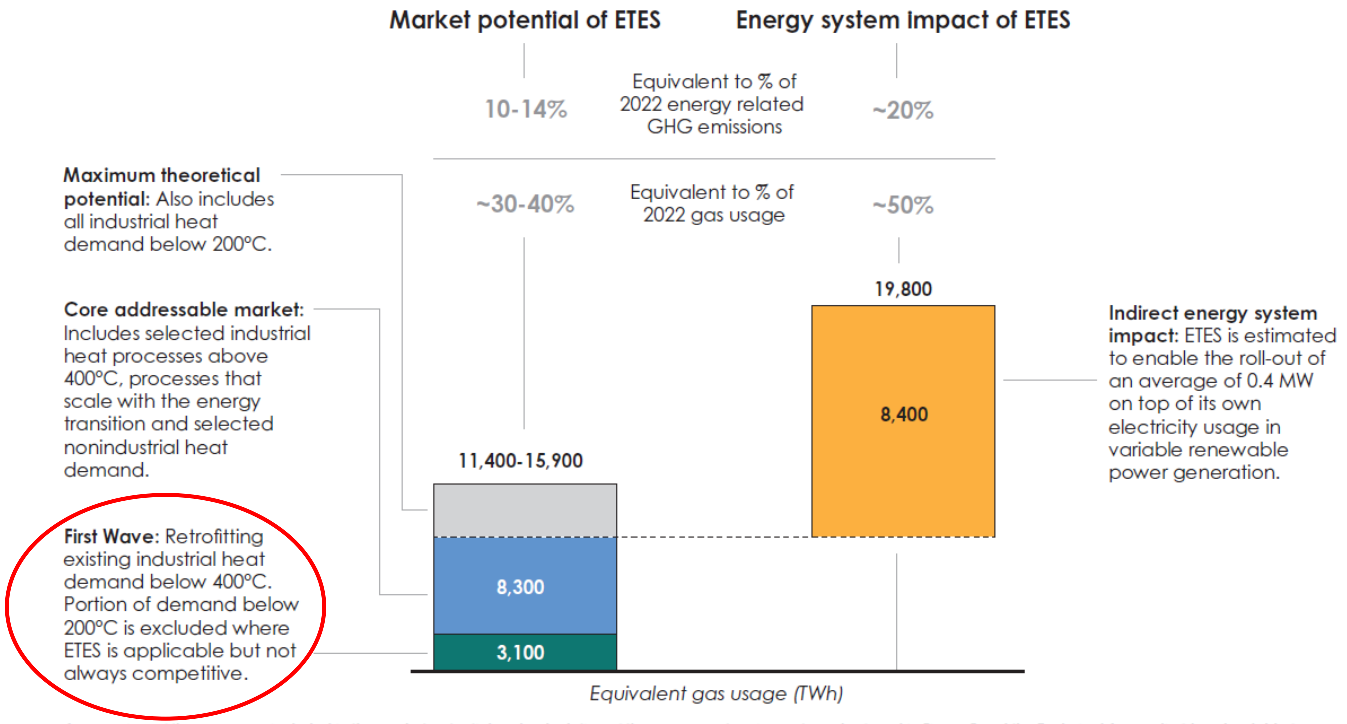
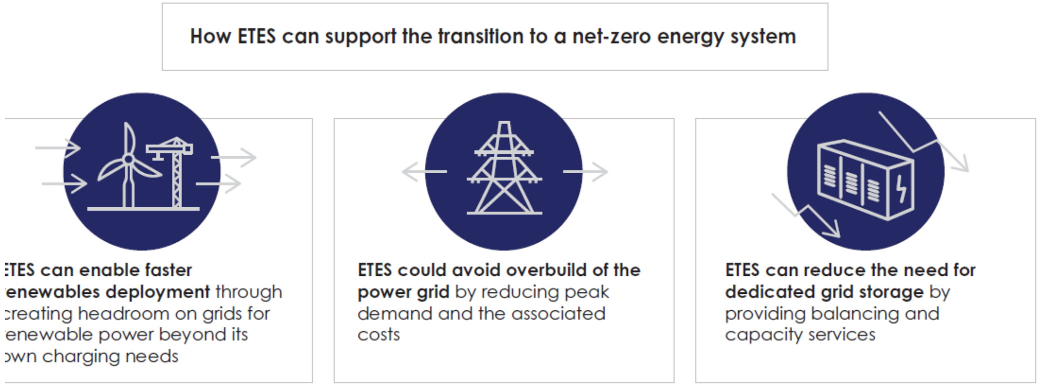
ETES Potential Market and Services to Power Systems



An overview of the processes included in the market potential and calculation of the energy system impact can be found in Figure 5 and the Technical Appendix (downloadable from https://systemiq.info/etes).

Source: UNFCCC data set (2021) — except for Australia (2019), International Aluminum Institute, World Steel Association, Eurostat, EuraTEX, USGS, Petrochemical Europe; Mind the Gap report by ETC, Fossil Fuel Role in Energy Transition report by ETC, EU heat profile is derived from EU Joint Research Center; US Heat Profile is derived from Energy Innovations' Decarbonizing Low-Temperature Industrial Heat in the U.S.; Understanding the Role and Design Space of Demand Sinks in Low-carbon Power Systems (Jenkins, 2021)



e: Jenkins and Van der Jagt, Understanding the Role and Design Space of Demand Sinks in Low-carbon Power Systems, 2021; Net-Zero Heat, LDES Council, 20XX, and Driving to ro Industry through Long Duration Energy Storage, LDES Council, 2023

Electrifying industrial heating systems globally will require investments **above € 1 Tn**

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ETES Technologies and Manufacturers

	SENSIBLE HEAT	LATENT HEAT	THERMOCHEMICAL HEAT
How it works	Increases temperature of a solid or liquid medium	Changing material phase	Endothermic and exothermic chemical reactions
Temperature range	<0 to 700°C *In progress to reach more than 1,500°C*	*In progress to reach 1,600°C*	*In progress to reach 900°C*
Storage duration	Intra day to days (or months at lower temperatures)	Intra day to days	Intra day to months
TRL	Commercially available	R&D to commercial available	Nascent
Providers (non exhaustive)	ANTORA, BUILD TO ZERO, BRENMILLER, Electrified Thermal Solutions, ENERGYNEST, ECHOGEN power systems, KRAFT BLOCK, KYOTO, MAGALDI, MALTA, RONDO, STORWORKS, 1414°	AZELIO, MGA THERMAL, TORC, THERMOPHOTON, 1414°	redoxblox, SaltX Technology

Source: Company websites; *Net-zero heat: Long Duration Energy Storage to accelerate energy system decarbonization*, LDES Council, 2023.

Key Messages

- **ES is a game changer**, the key enabler of an energy transtition based on electrification and VRE (wind, PV).
  ES and VRE grow up together convergently. By 2030, worldwide, VRE capacity will growth **3x**, ES **6x**.

- When VRE penetration will overtake **50%**, the needs for ES will growth with a **slope 100 times higher**.
  Es. VRE penetration of 70% (12x, i.e. **2050**) → ES x28 (!), i.e. **hundreds thousands GWh**. Is BESS+PH enough?

- **Industrial heat** absorbs **20%** of global final energy demand and **75%** of it is supplied by fossil fuels.
  ETES can provide the power system with ES services (balancing, flexibility, time-shifting, etc.)
  absorbing excess VRE production (VRE penetration >50%) **while decarbonizing industrial heat**.

- ETES potential market is estimated **3,100 TWh** (electrified heat demand) worldwide in a **1st phase (<400 °C)**,
  about **8,600 TWh** in a **2nd phase (>400 °C)** plus **other 8,400 TWh of additional VRE** enabled by ETES itself,
  for a **total potential of almost 20,000 TWh**, the same order of magnitude of today's global electricity demand.

- ETES technologies are **ready** (TRL 9), competitive, **free of critical materials**, recyclable/circular, modular,
  site unconstrainted, scalable, easy to install, with long life (>30 years) and long duration storage capacity.

- The needs for energy storage in power system (VRE >50%) and the
  excess of (free) renewable electricity are ETES' drivers in the long run.

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THANK YOU

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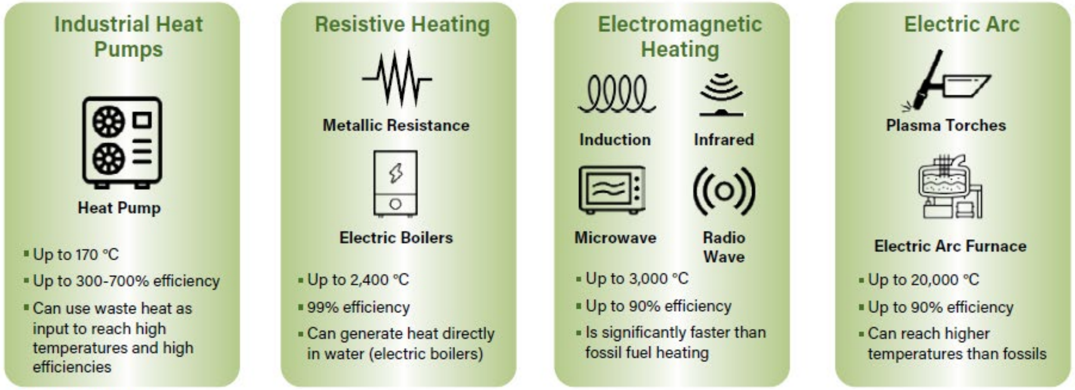
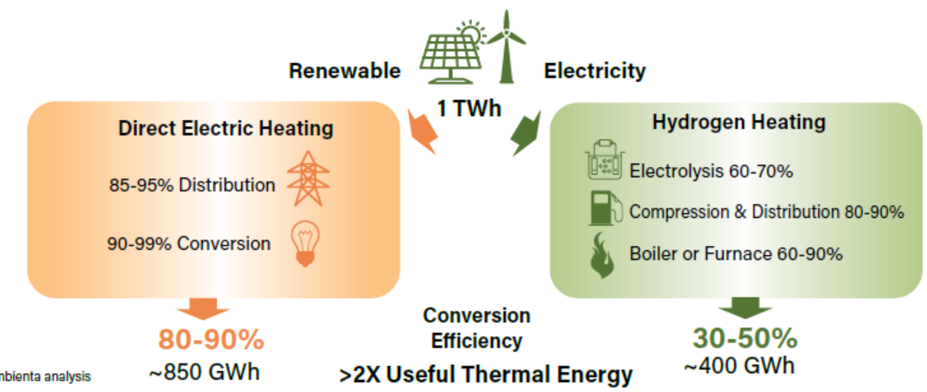
Main Heat Electrification Technologies and Benefits

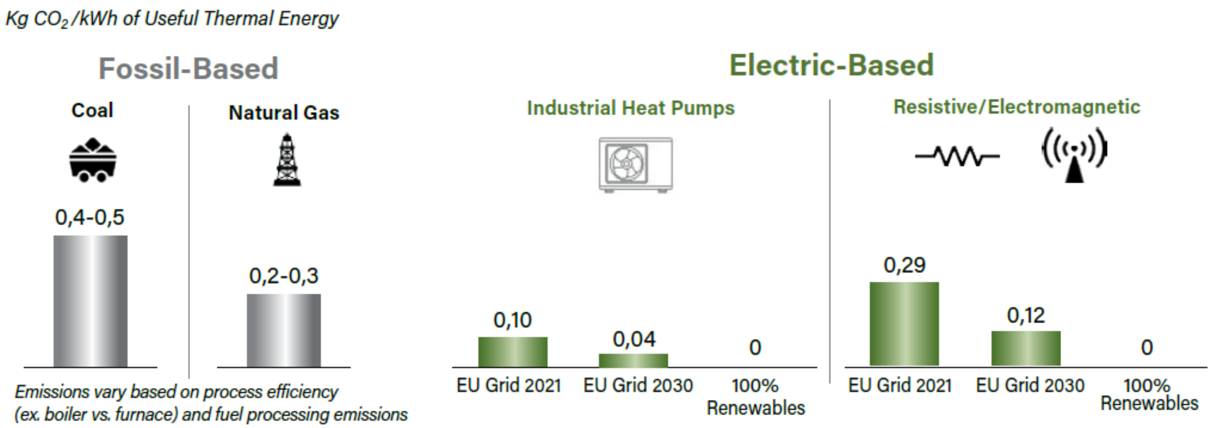


Source: Ambienta analysis

Direct vs. Indirect (Hydrogen) Electrification Efficiency



Source: Ambienta analysis



Source: Ambienta analysis, Eurostat

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