Applications for Thermal Energy Storage and Conversion in the industrial field

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- Priorities

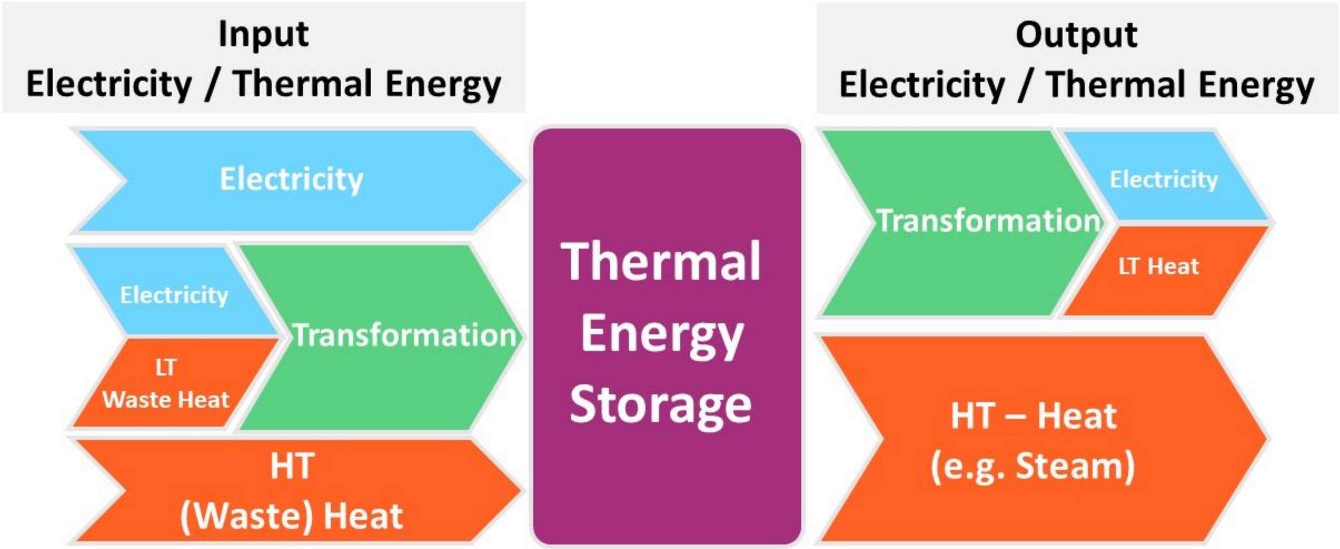
References:

[1]: Manente G, Ding Y, Sciacovelli A. A structured procedure for the selection of thermal energy storage options for utilization and conversion of industrial waste heat. Journal of energy storage. 2022 1;51:104411.

[2]: Niknam PN, Barberis S, Sciacovelli A. High temperature industrial thermal energy storage – Assessment of potential applications and benefits toward industrial decarbonization; Proceedings of Eurotherm Seminar, Lleida; 24/26May 2023

Applications for TES and Conversion in Industrial Fields

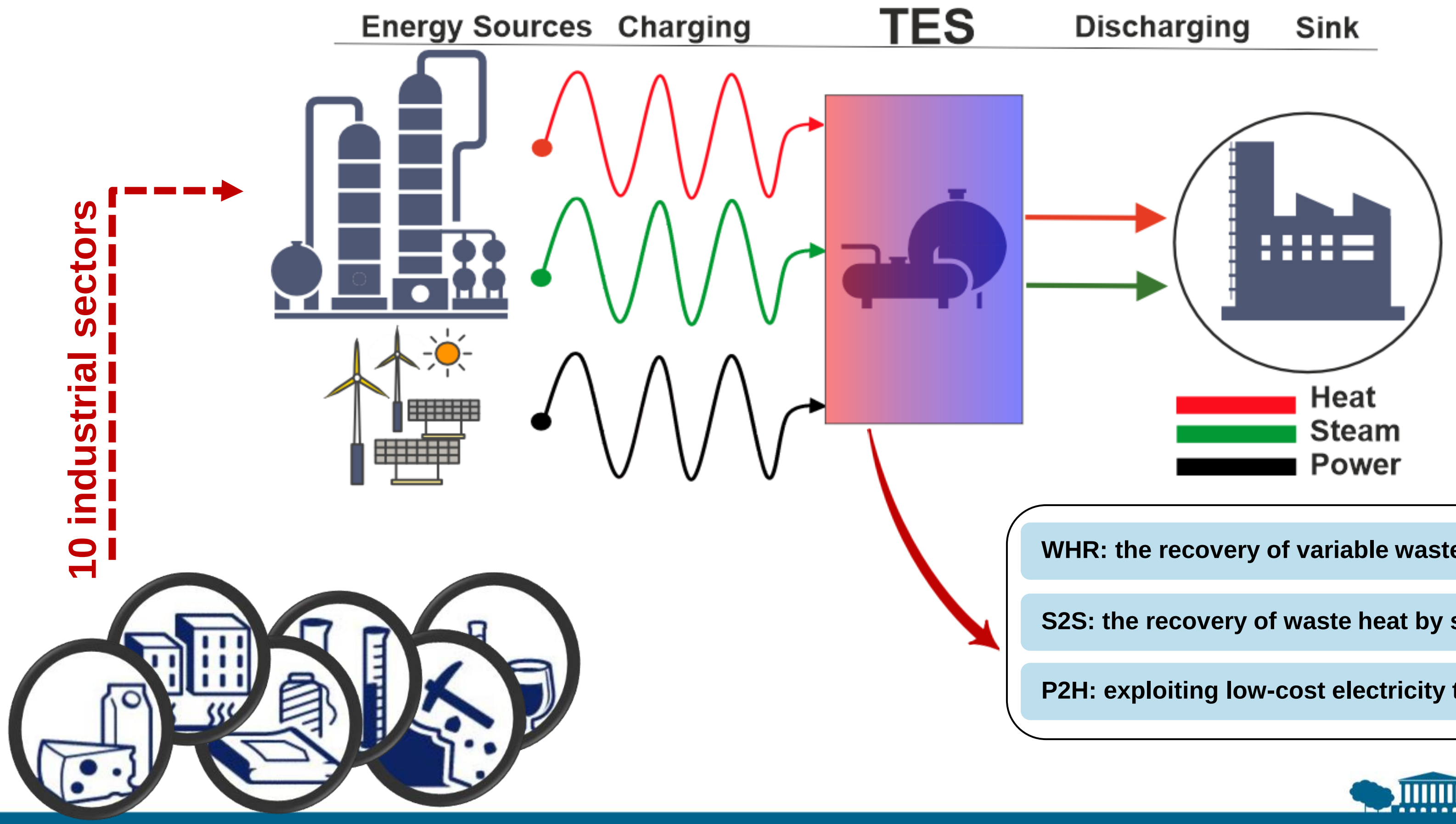
- General framework for assessment of integrated Storage and Conversion



*IEA Task XX: Zero-carbon (industrial) heat & power supply; Starts in Q1 2024

Introduction and scope of research

- The global industrial clusters emit around 8.8 Bt of CO_2 annually, equivalent to 24.2% of global emissions.
- TES integration in industries for supplying heat and steam

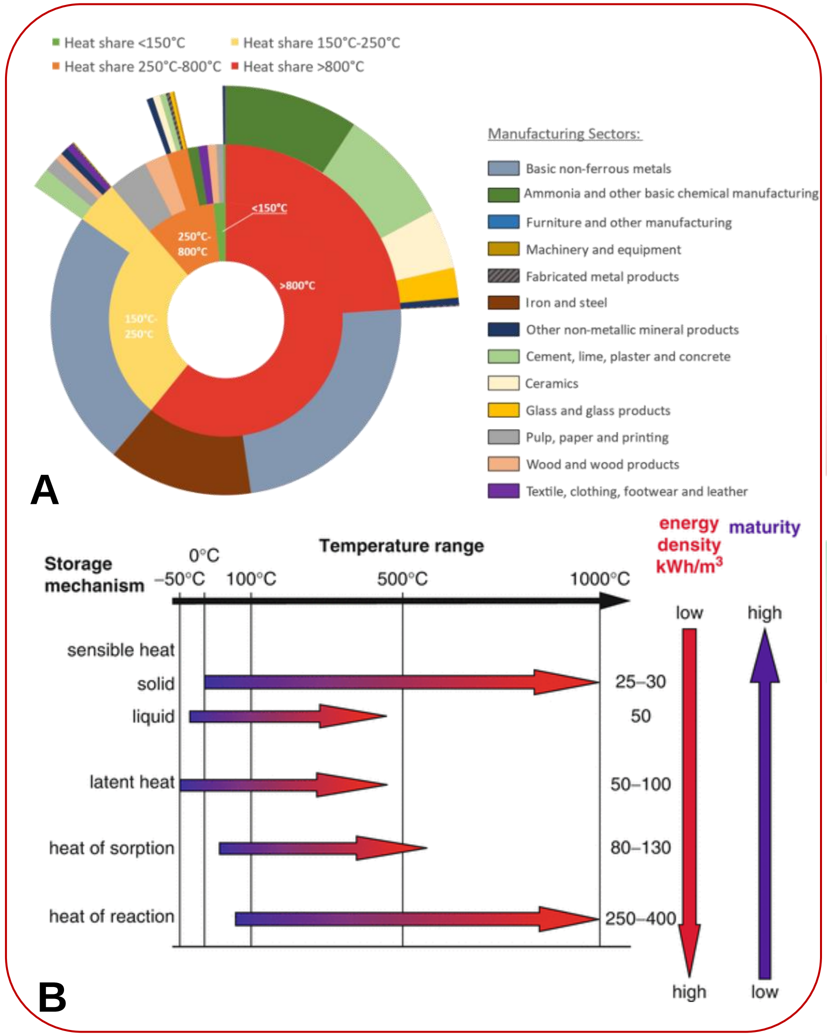


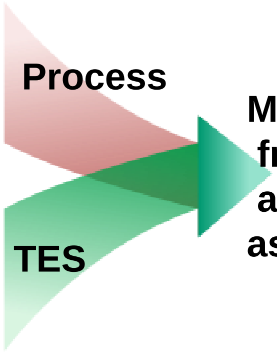
WHR: the recovery of variable waste heat sources available in industrial processes

S2S: the recovery of waste heat by steam storage to balance steam supply/demand

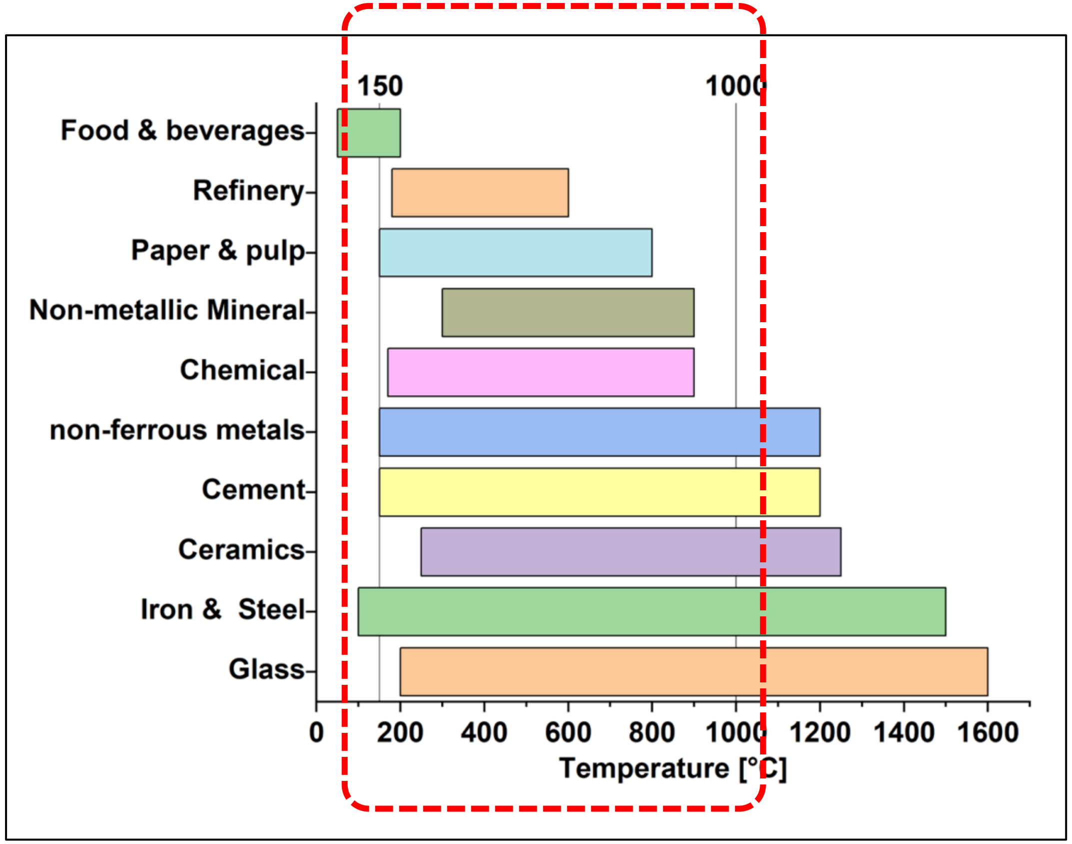
P2H: exploiting low-cost electricity to fulfil 50% of the plant process heat demand

Process-level data & temperature ranges





Making a framework for a comparative assessment



A: https://www.racefor2030.com.au/
B: DOI: 10.1007/978-1-4419-0851-3_684

Modelling Methodology and Assumptions

WHR

TES potential for WHR
Number of Cycles pa=360
cycle time (CT): 6 hr
Reference cost= 100 €/kwh

$$Q_{TES,WHR} = Q_{plant} \times Q_r \times CF_{TES}$$

CF: temperature range correction factor

S2S

TES potential for steam supply
Number of Cycles pa=720
cycle time (CT): 3
Reference cost= 75 €/kwh

5% of steam consumption

P2H

TES potential for power to heat
Number of Cycles pa=360
cycle time (CT): 12
Reference cost= 125 €/kwh

Up to 50% process heat demand

$$C_{TES} = Q_{TES} / 24 \times (CT/2)$$

$$C_{f,sav}^{plnt} = C_{TES} \times NC \times \text{Gas Price}$$

CO_2

$$C_{C,sav}^{plnt} = C_{TES} \times NC \times \text{Emission} \times \text{EUETS}$$

$$\text{CapEx} = \text{CapEx}_{ref} \times (C_{TES}/C_{TES,ref})^{\gamma}$$

$$PBP_{TES} = \text{CapEx}_{TES}/F$$

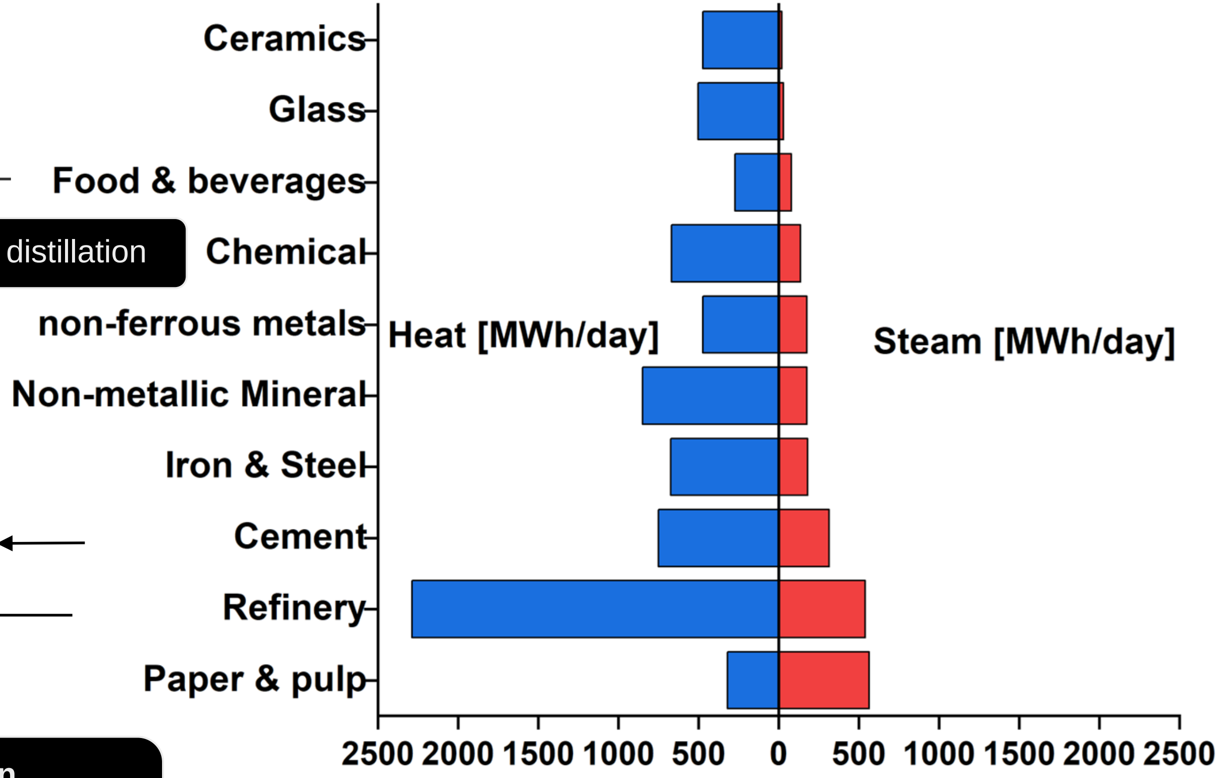
5-year average Carbon Price (EU ETS)	€/tCO_2	74.95
CO_2 emission from NG-based energy	gCO_2/kWh	230
Steam / Electricity / NG price	€/kWh	0.034 / 0.082 / 0.027
5-year average Electricity discount	%	64

Plant-level process data

Plant-level process data (heat and steam demand) are taken from EU-level investigation and available database from Germany, Netherlands, and some non-European countries

reformer; distillation

Boiling & CIP



heating kiln

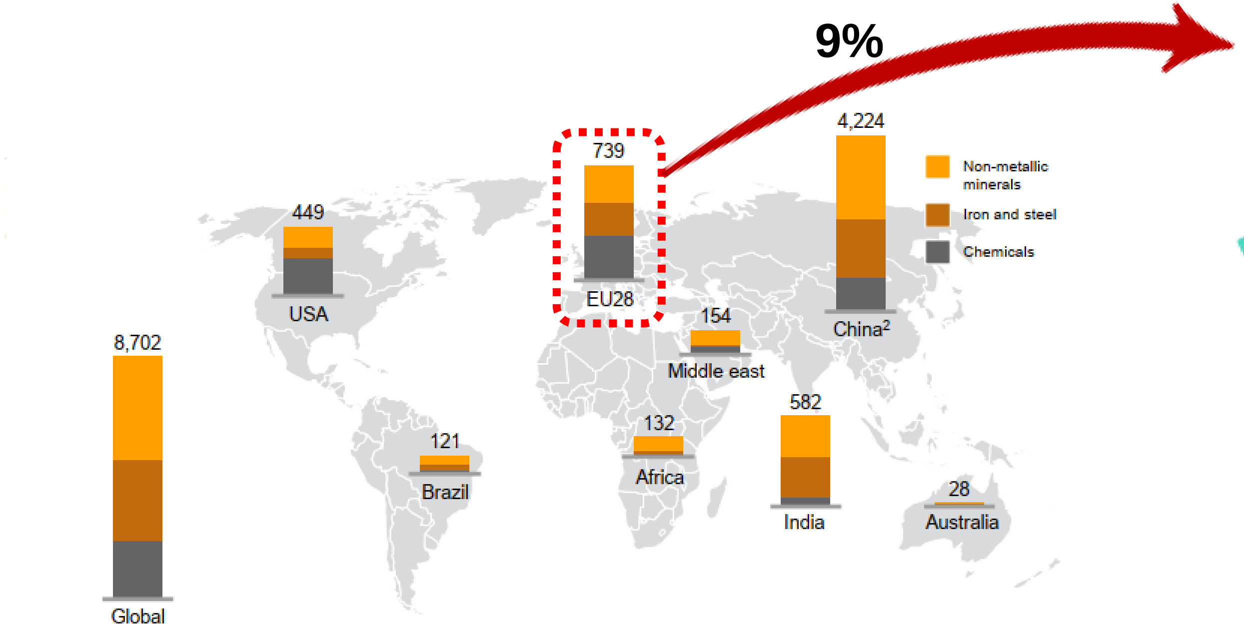
Distillation, reformers
crude fractionator
Steam cracking
Endothermic reactors

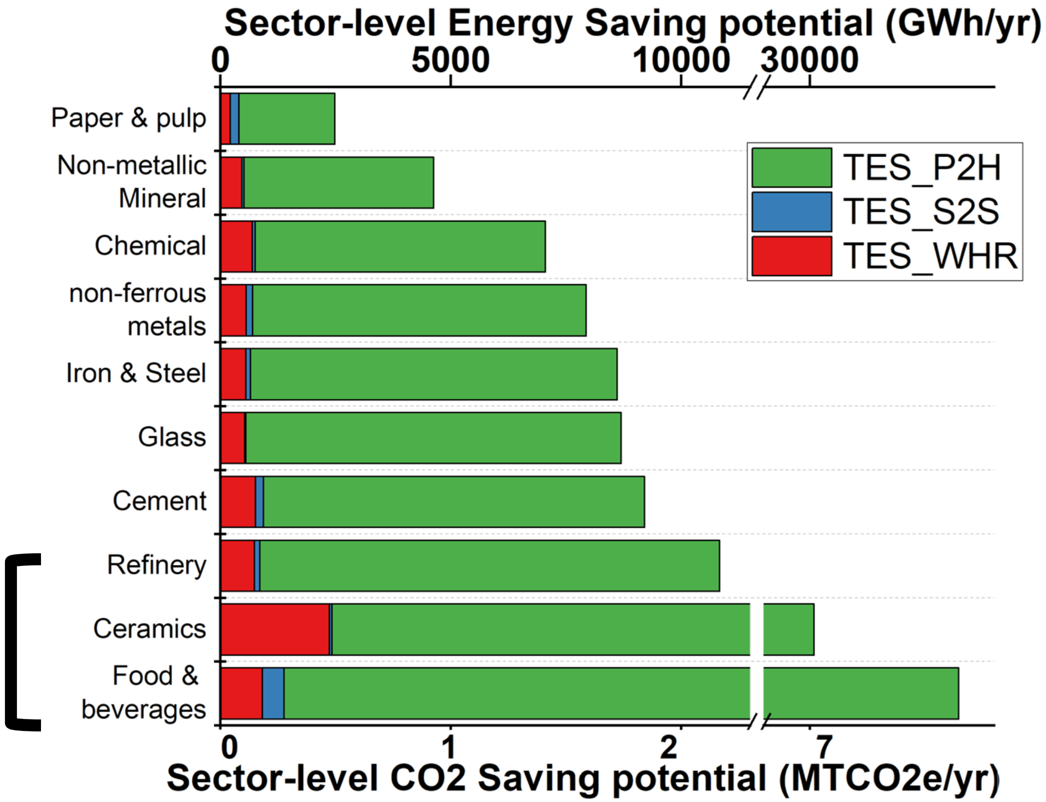
stock preparation
Bleaching, Drying
washing

Plan-level to Sector level

Potential in energy and CO_2 saving in three TES applications

$$PI_{sct,EU} = \sum_{sct} (N_{EU}^{plnt} \times C_{saving}^{plnt})_{WHR} + (N_{EU}^{plnt} \times C_{saving}^{plnt})_{S2S} + (N_{EU}^{plnt} \times C_{saving}^{plnt})_{P2H}$$

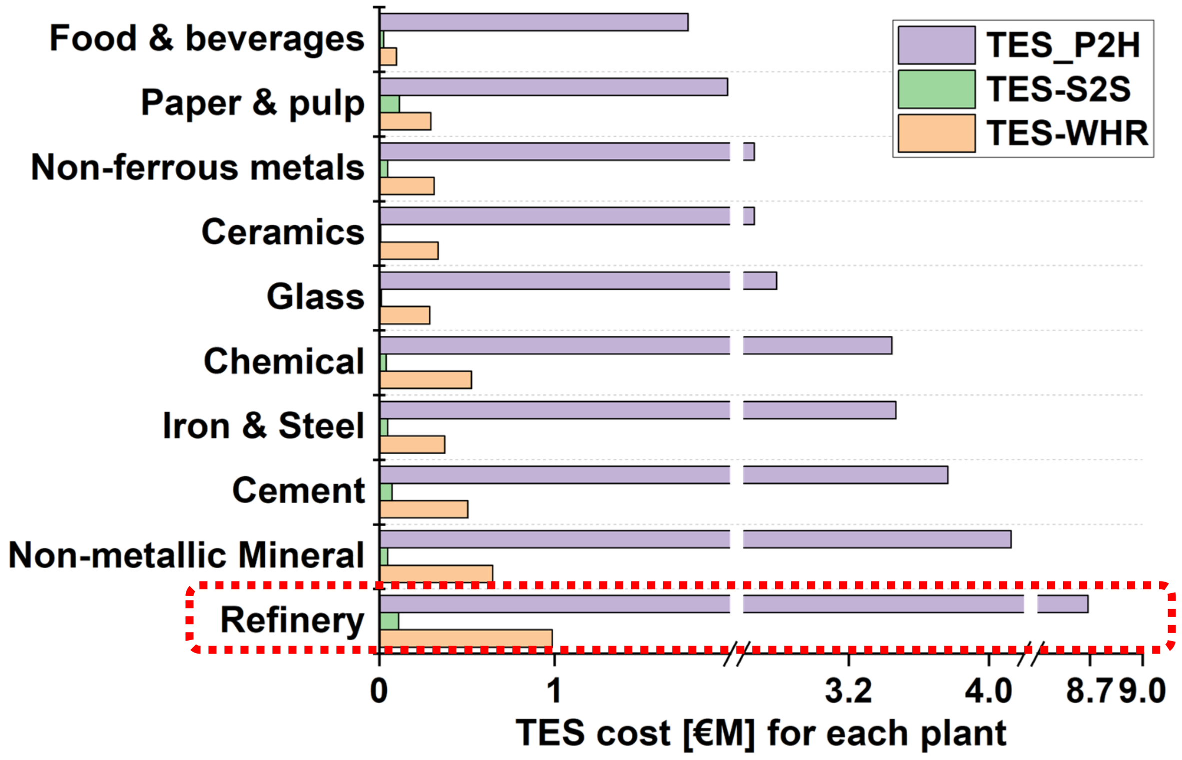




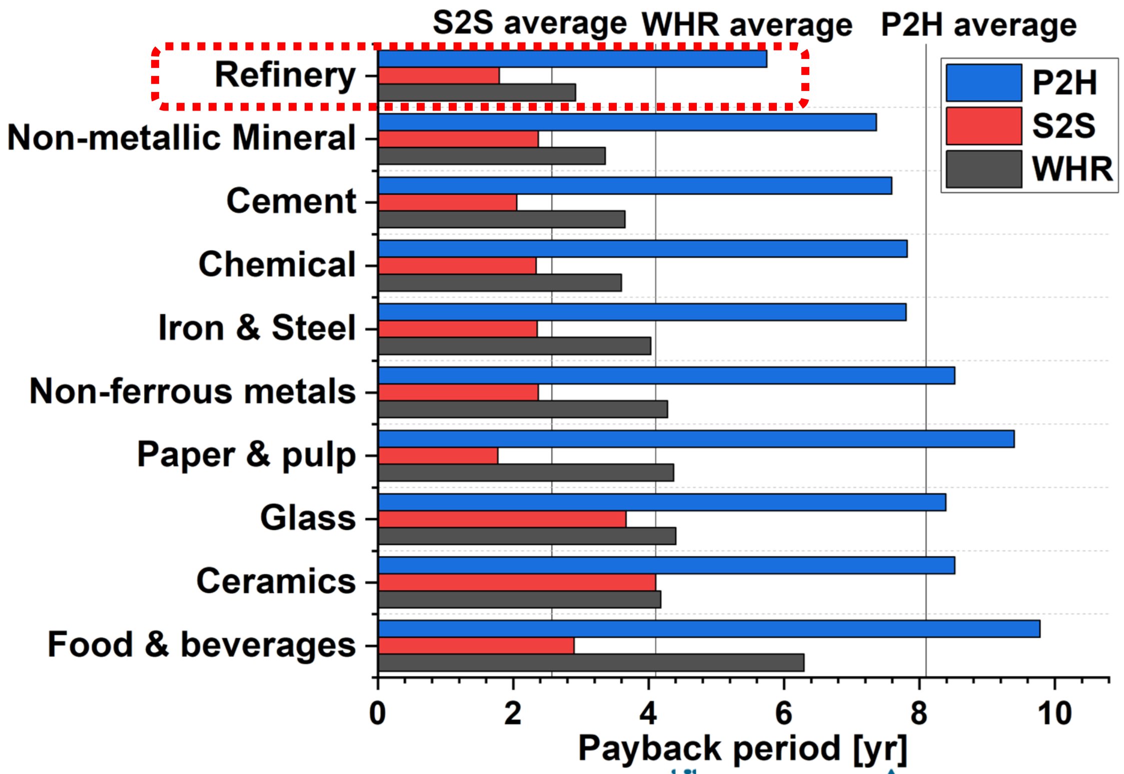
Ref: Decarbonization of industrial sectors: the next frontier, McKinsey 2018

Plant/sector level Economic assessment

Plant-level CapEx

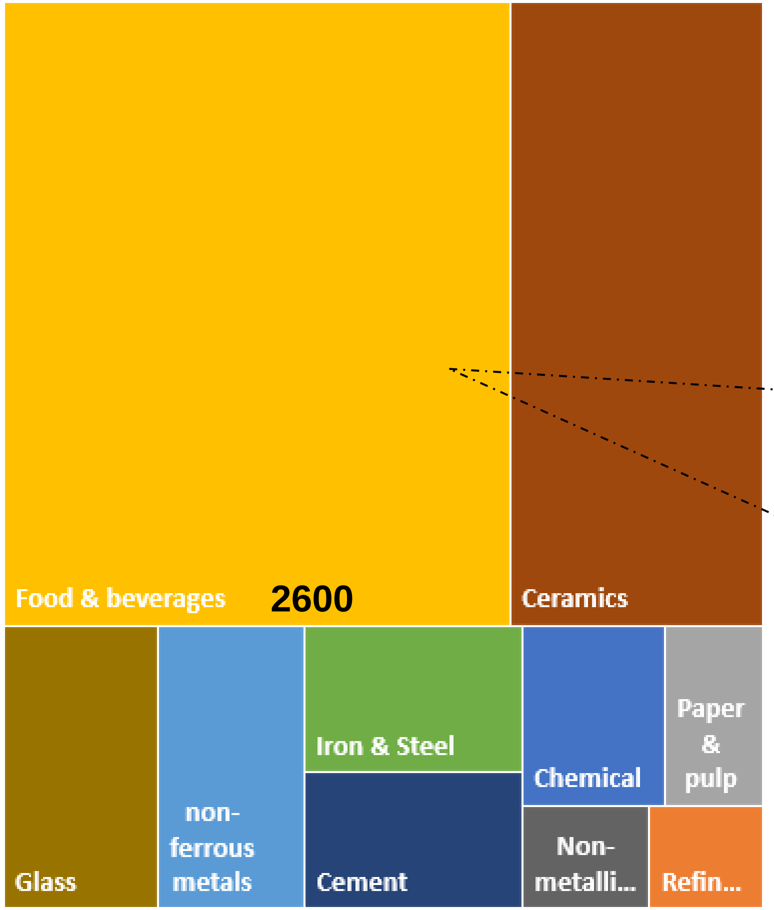


Payback period

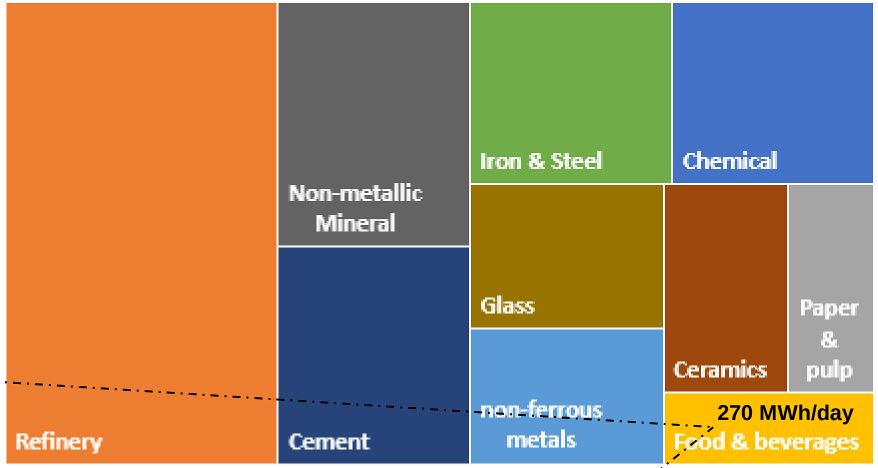


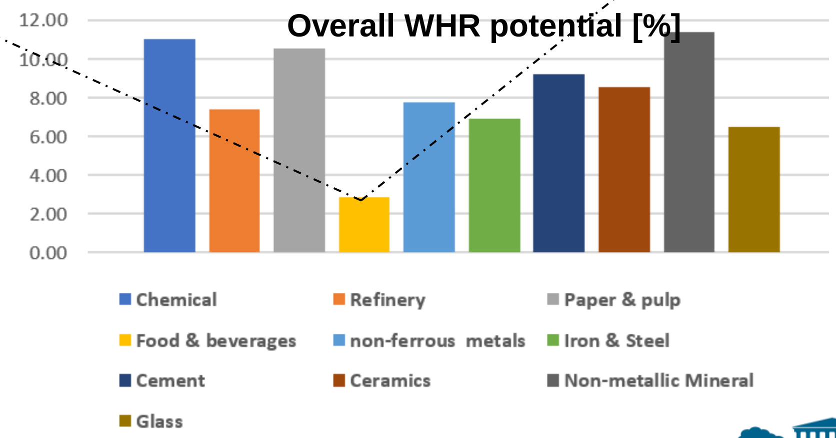
Top priorities for TES Investment in sector level across the EU

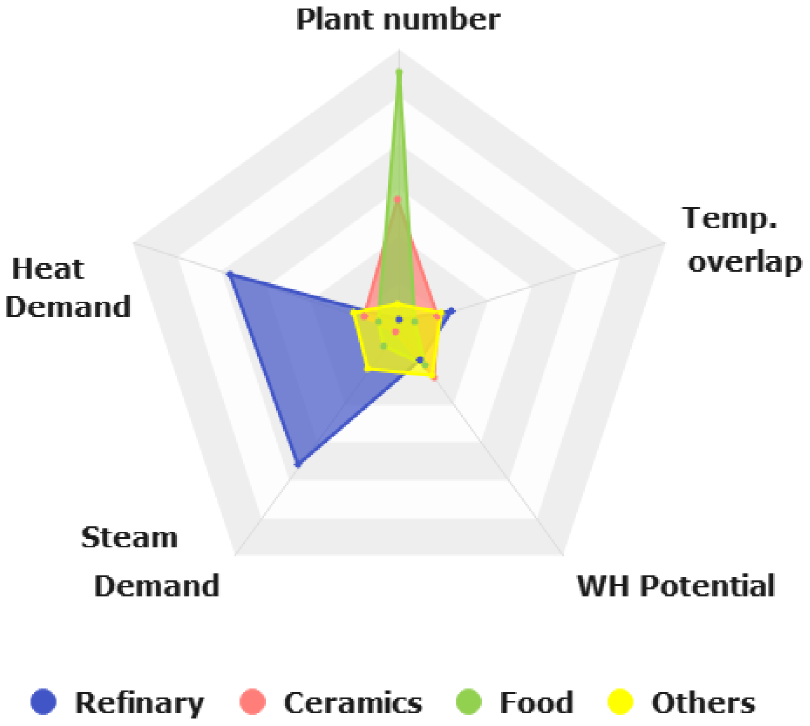
N of active sites across the EU, (total 5700)



Relative Heat demand

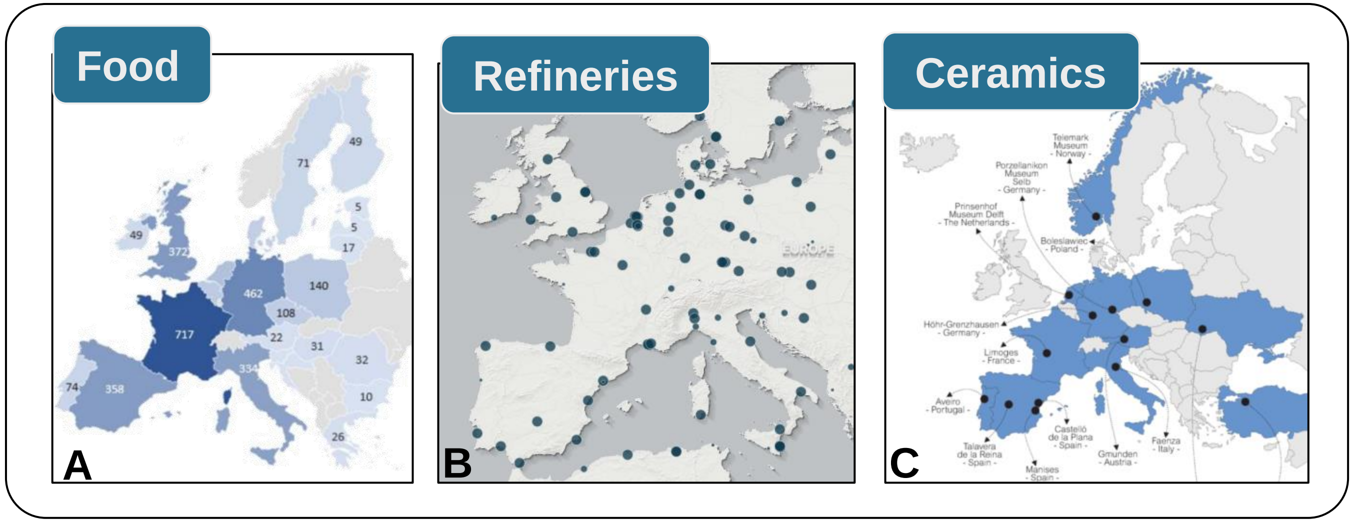




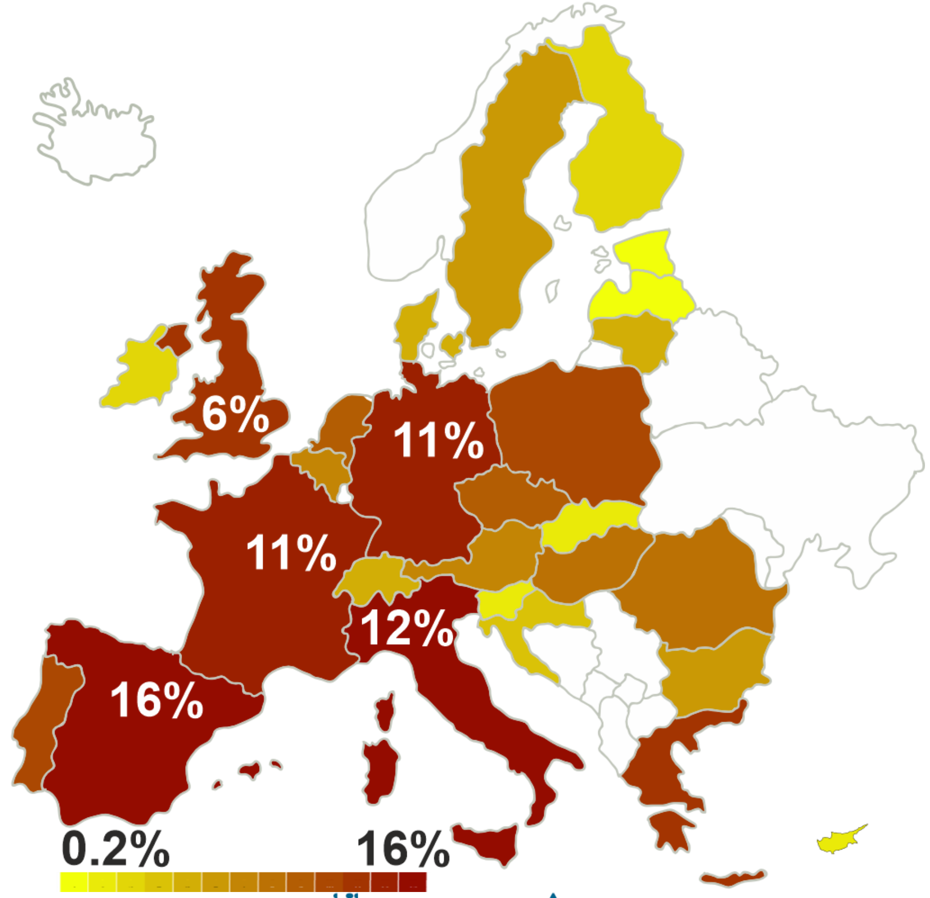


EU-Investment top priorities in Country-level

Statistics on sectoral sites across the EU



Sector-level potential energy across EU ($\mathrm{PI}_{\mathrm{ctry}}$)



$$PI_{\mathrm{ctry}} = \frac{\sum_{sct}(N_{\mathrm{ctry}}^{plnt} \times C_{sav}^{plnt})_{WHR} + (N_{\mathrm{ctry}}^{plnt} \times C_{sav}^{plnt})_{S2S} + (N_{\mathrm{ctry}}^{plnt} \times C_{sav}^{plnt})_{P2H}}{\sum_{sct}(N_{\mathrm{EU}}^{plnt} \times C_{sav}^{plnt})_{WHR} + (N_{\mathrm{EU}}^{plnt} \times C_{sav}^{plnt})_{S2S} + (N_{\mathrm{EU}}^{plnt} \times C_{sav}^{plnt})_{P2H}} \times 100$$

$$(\forall\ sct \in \{\mathrm{Refinery, Ceramics, Food}\},\quad \mathrm{ctry} \in \{\mathrm{EU28}\})$$

A https://fooddrinkeurope.eu
B https://www.europeanrouteofceramics.eu
C https://climatetrace.org/map/oil-and-gas-refining-co2e100

Conclusion

- TES potentials is quantified for

	WHR	S2S	P2H
PBP [year]	2.9 … 6.3	1.7 … 3.7	5.7… 8.5
TES capacity	4 … 21 MWh	0.1 … 1.8 MWh	34 … 200 MWh

Multiple parameters impact the TES potential in process level

Temperature range, Heat supply/demand, and Process cycle and **level of intermittency, Number of sites**

- **Refineries**, **ceramics**, and **food industries** with the highest impact on emission reduction
  - More than 4000 active sites across the EU
  - Up to 70 GWh pa across the EU
  - Up to 17 MtCO_2e pa saving across the EU

- Countries are expected to gain differently from TES implementation

References

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Thank You

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