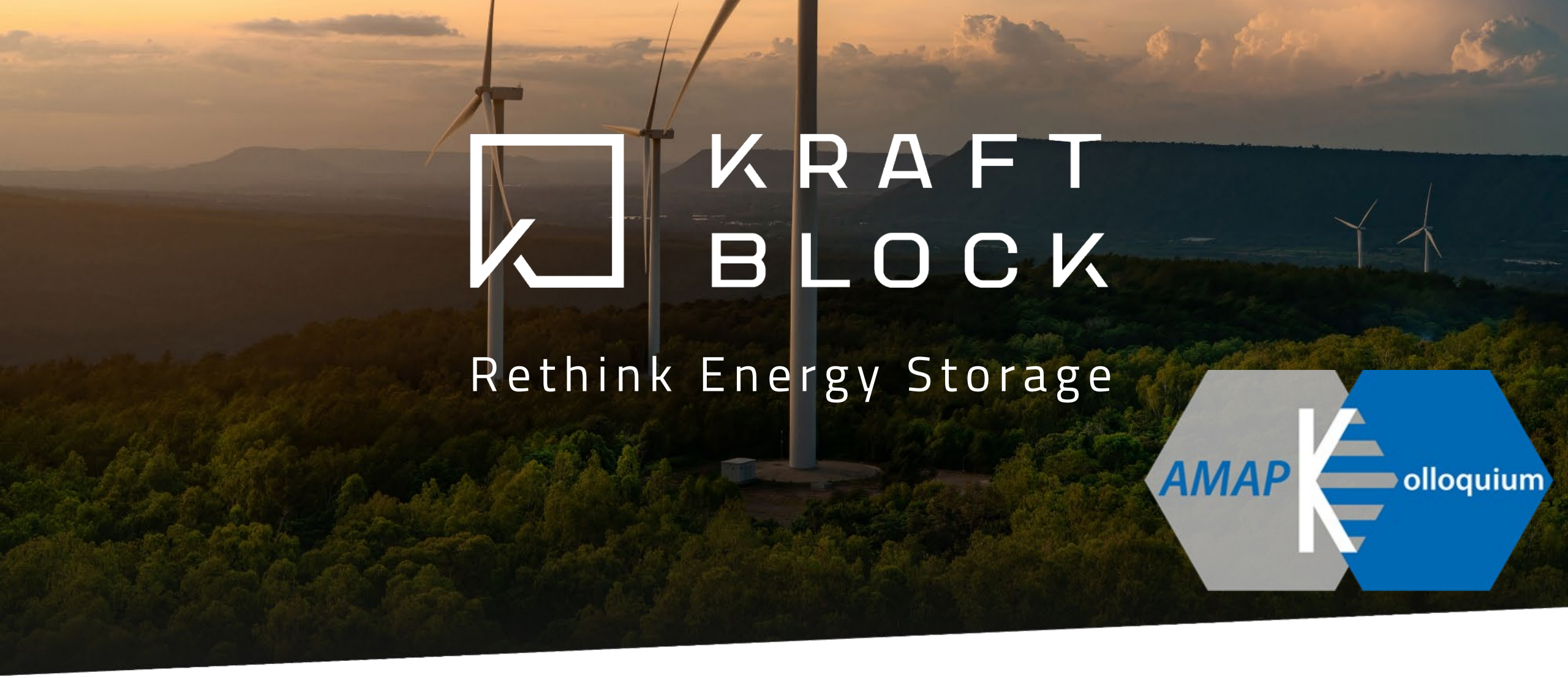
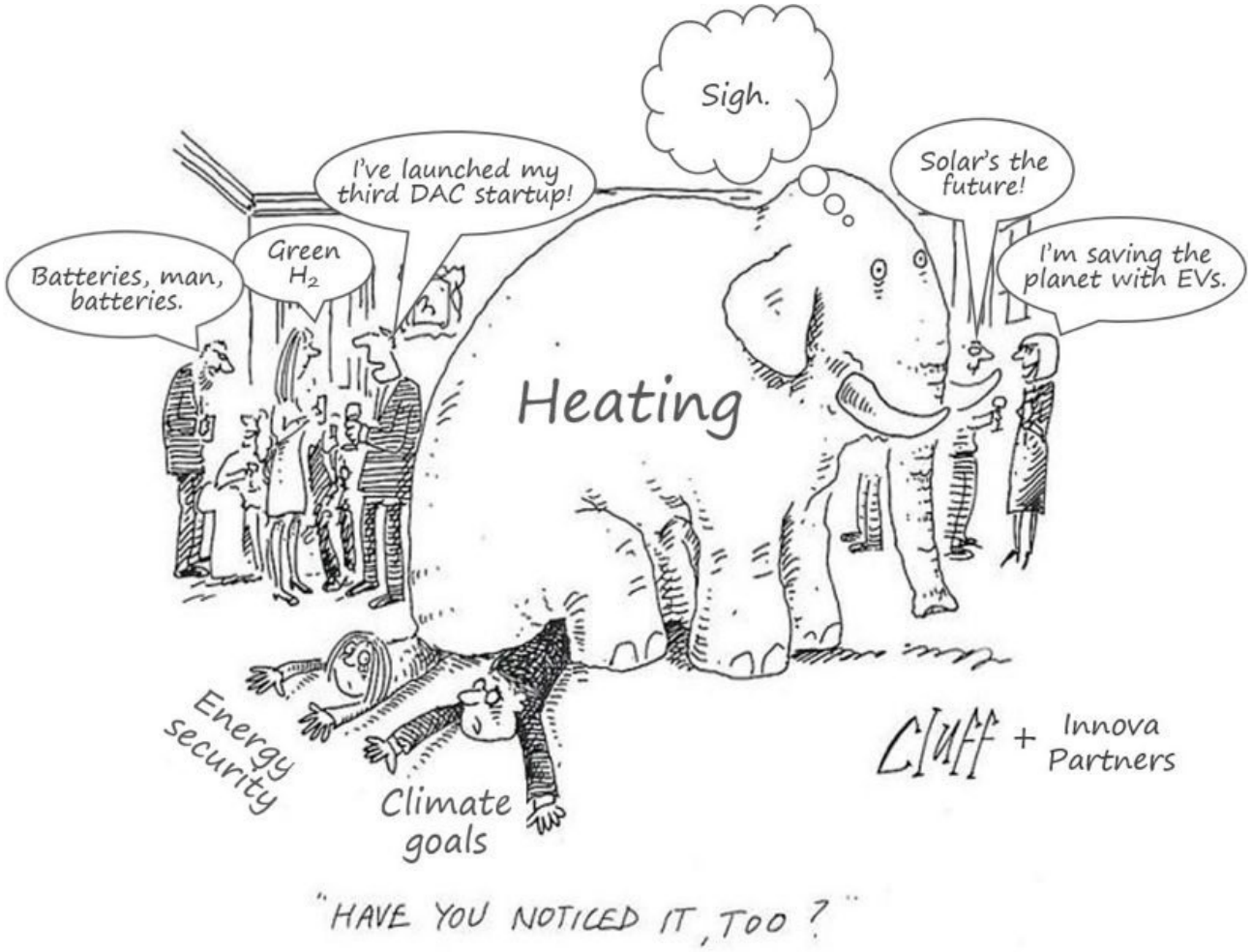


High-temperature Heat Storage for Decarbonization in the Metals Industry

Heat – The Elephant in the Room

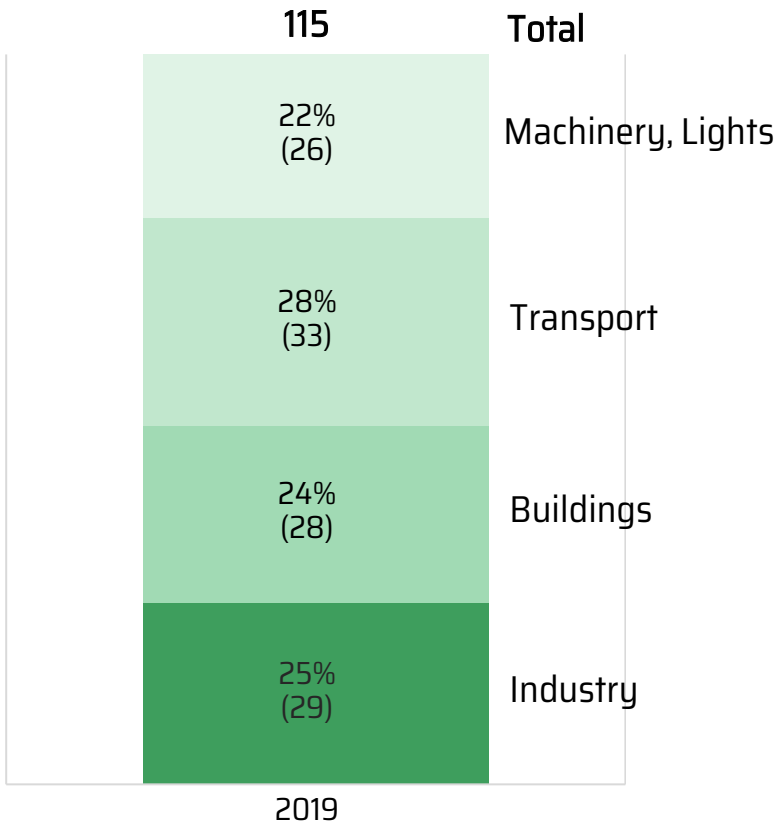


Heat in perspective

- Over 50% of the globally consumed energy is heat
- In industries process heat makes up to three quarters of the energy demand
- 40% of global emissions are due to burning fossils for heat processes

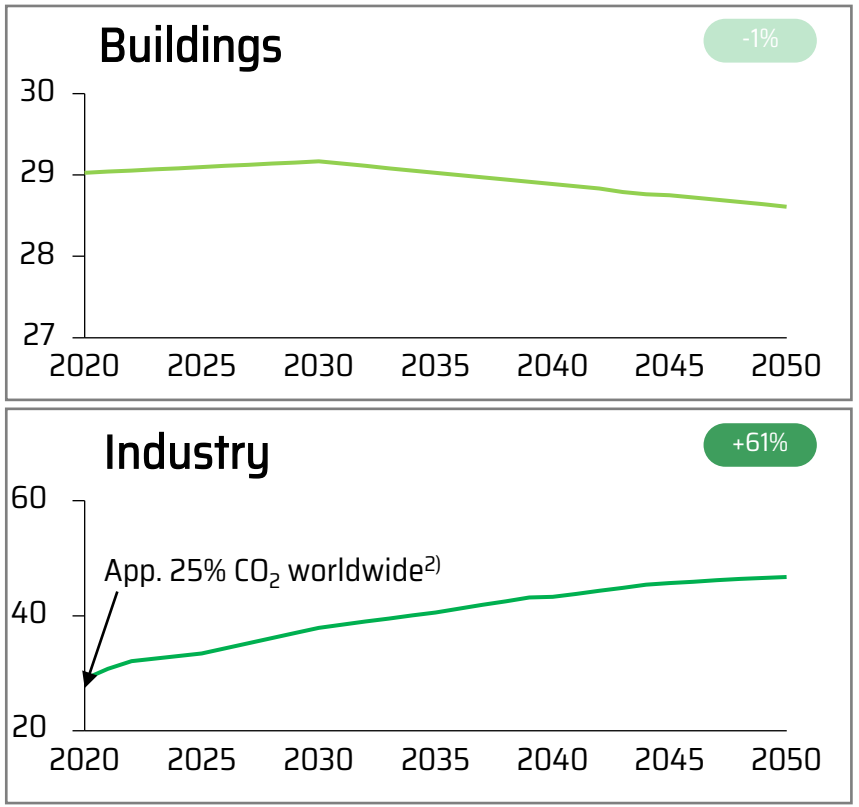
Key Insights to Global Energy Consumption

World Energy demand per sector
[PWh, % of Total]



1) Petawatt-hour (PWh) is equivalent to 10^9 Megawatt-hours (MWh)

Development Energy demand[PWh]



2) https://ourworldindata.org/emissions-by-sector#energy-electricity-heat-and-transport-73-2

Heat in perspective

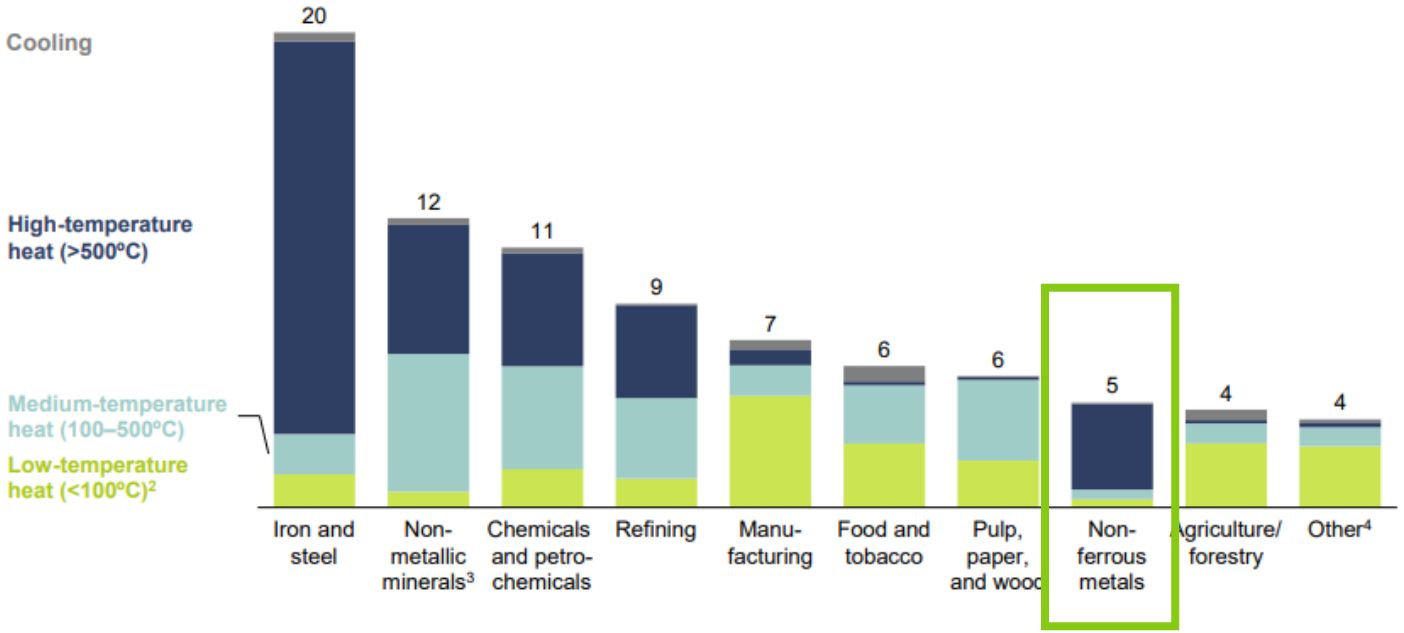
- Machinery, Lights and Transport is a question of electricity
- Buildings and Industry predominantly need heat (60%-90%)
- Until 2050: Main growth in energy consumption is heat in industries

Process Heat in Industries

Exhibit 4

Industrial energy consumption is concentrated in high-temperature applications

Global industrial final energy consumption by sector[1]
Exajoules, 2019



1. Excludes ~20 EJ of industrial final energy consumption due to insufficient reporting.
2. Includes hot water and space heating.
3. Includes ceramics, glass, and cement.
4. Includes energy industry own use.

Source: McKinsey Global Energy Perspective

Heat in perspective

- Metals industry almost exclusively needs temperatures above 500°C
- Medium-temperature knows no superefficient solution
- How are fossil fuels replaced?

Solutions for the Heat Transition

Renewable electricity

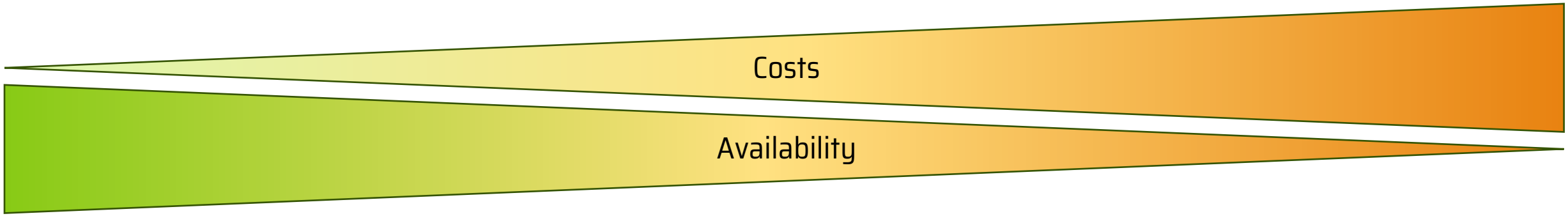
- Conversion without losses
- Use is safe
- Generation is cheap

Bio energy

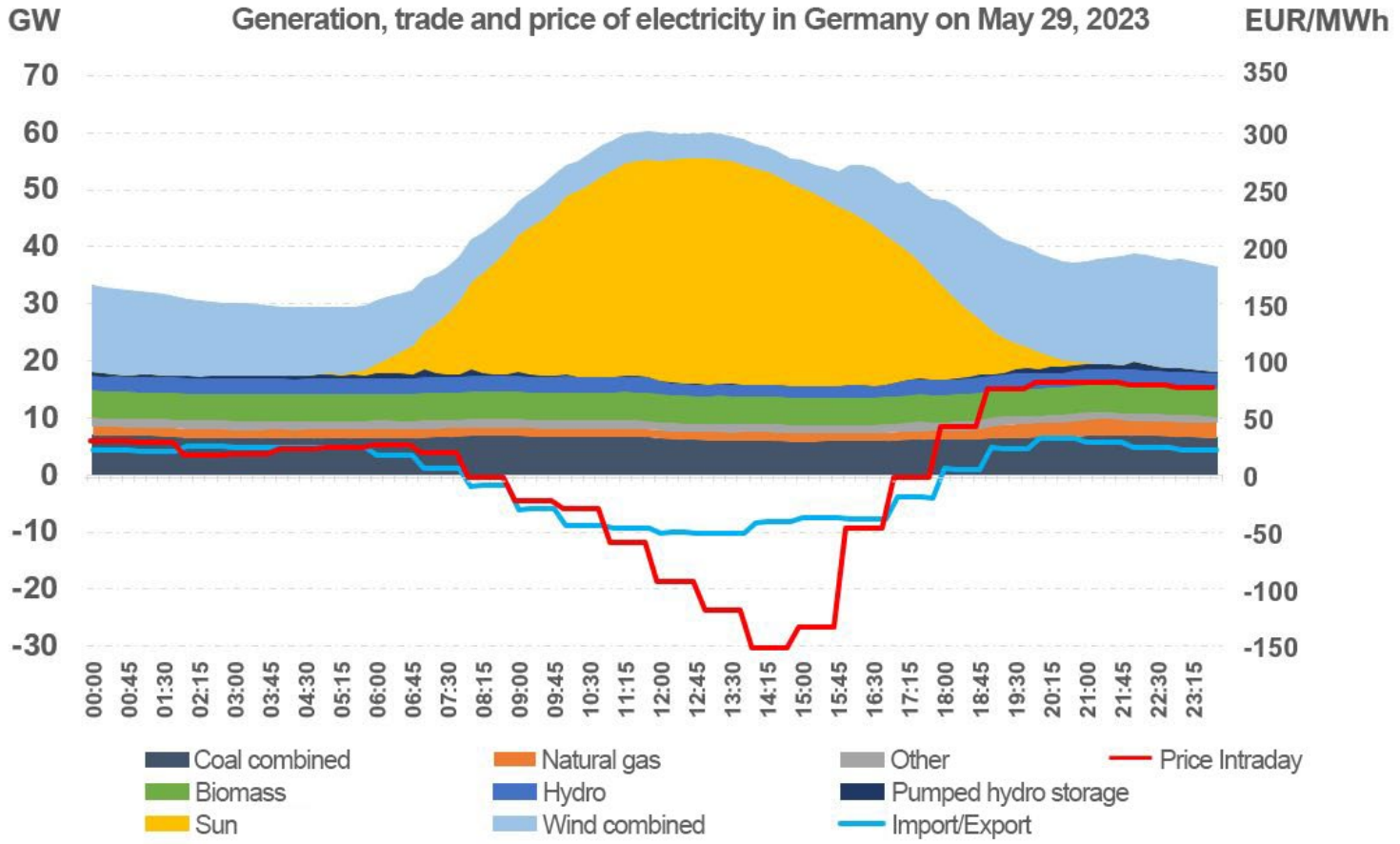
- Usable in existing infrastructure
- Generation uncomplicated and decentraliced

Hydrogen

- High temperatures
- Can be produced renewable
- Long-duration storage



Electricication's problem

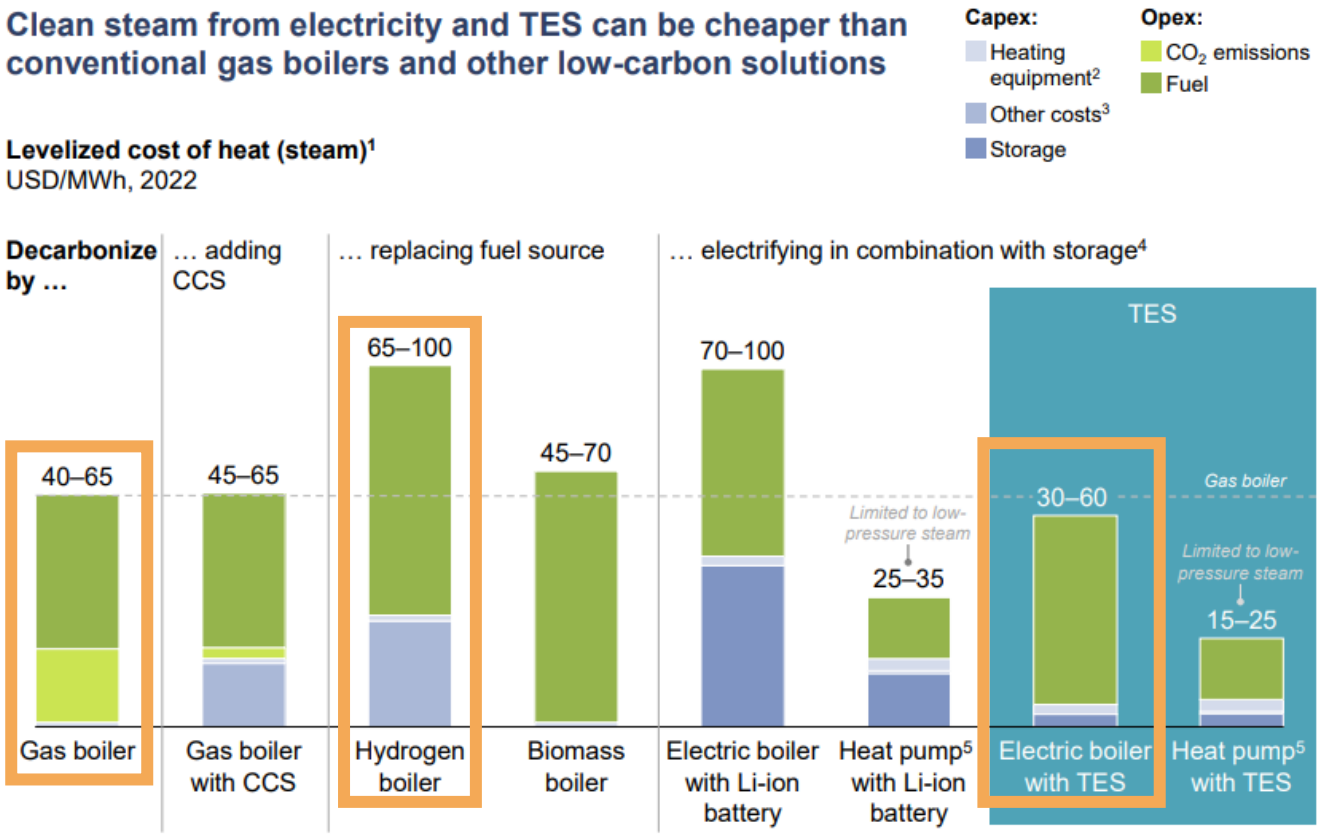


Electrification

- We have a lot of cheap **surplus** power that is unused
- We lack **grid stability** due to **volatile** sources and expansion is slow
- Prices of electricity are high when bought continously
- Grid fees are a part of high prices

Costs of Thermal Energy Storages

Clean steam from electricity and TES can be cheaper than conventional gas boilers and other low-carbon solutions



1. Ranges reflect representative fuel prices. Gas (USD 6–12/mmBTU), electricity (USD 25–50/MWh), biomass (USD 200–350/t). In the hydrogen boiler case, hydrogen production costs amount to USD 2.1–3.2/kg of hydrogen.
2. Boiler, heat pump, and charging equipment.
3. Electrolyzer, CCS.
4. Assumes on-site renewables.
5. High-temperature industrial heat pump. Maximum achievable steam temperature is ~160°C.

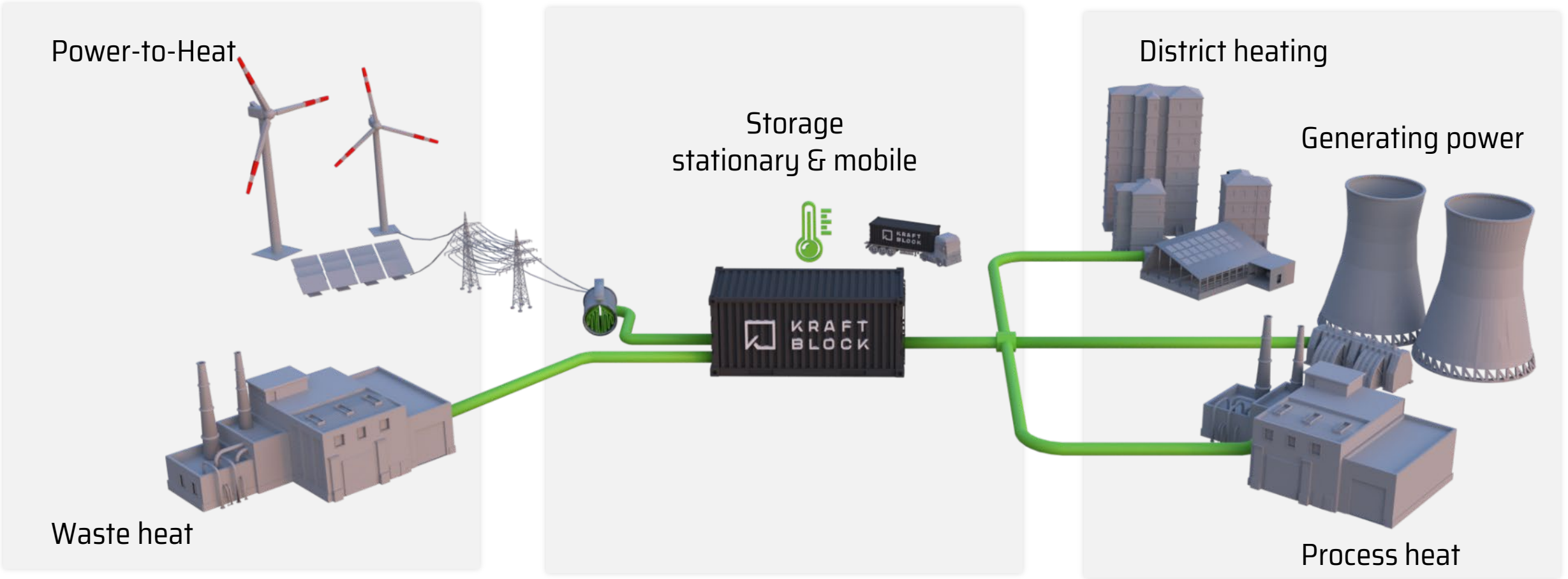
Source: LDES Council 2023, Systemiq 2024

Steam production

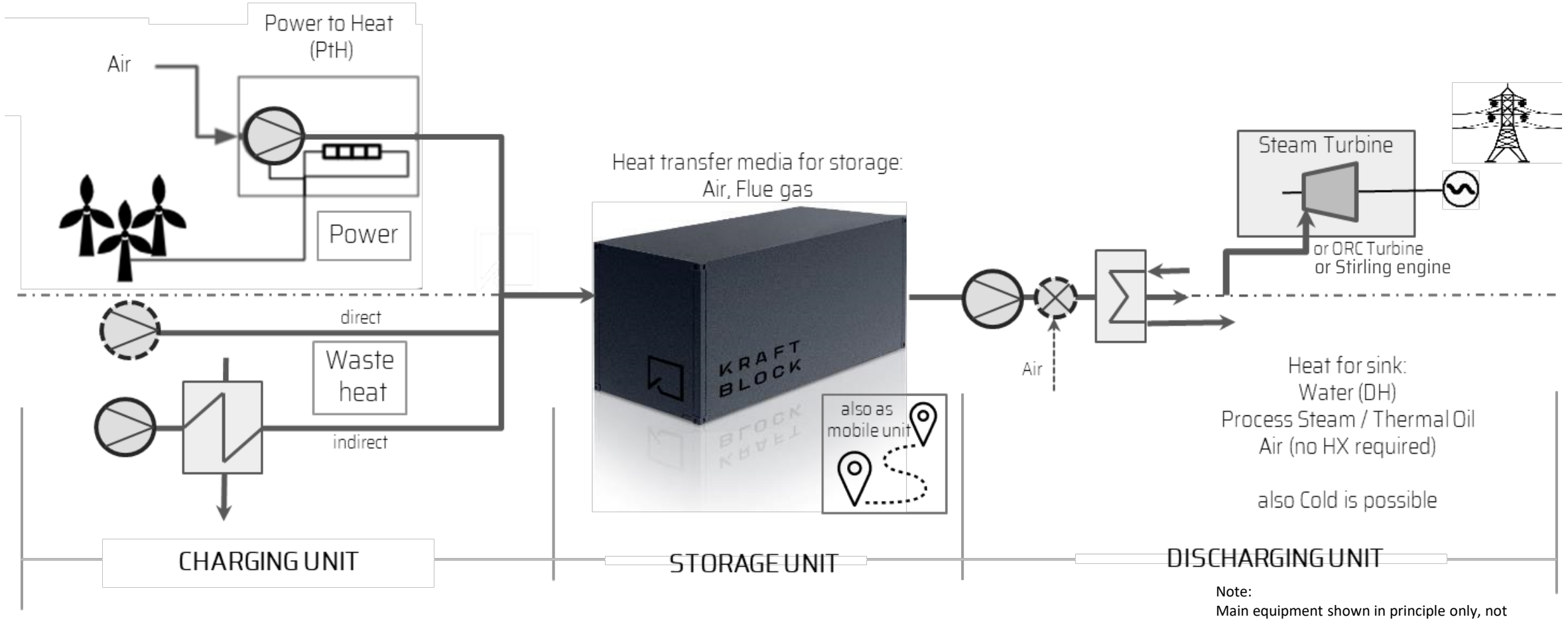
- Levelized cost of heat (steam)
- Electricity with heat storage cheapest option for steam above 160°C
- Hydrogen most expensive
- CO_2-prices are included

Storage Innovation Kraftblock

Overview of Applications



Scheme Options



Note:
Main equipment shown in principle only, not in correct process sequence (e.g., fan position)

Kraftblock's Storage

From 350°C up to **1,300°C (2400°F)**

Modular, scalable storage **to GWhs**

Storing **hours** and **weeks**

Highly economic and multifunctional **high-temperature energy storage**

Patented Systems

Capacity of up to **1.2 MWh/m³**

High durability of 40+ years

Up to **85% recycled** materials

The Storage Cycle

Charging

Hot air is blown through the storage. The storage material absorbs the heat.

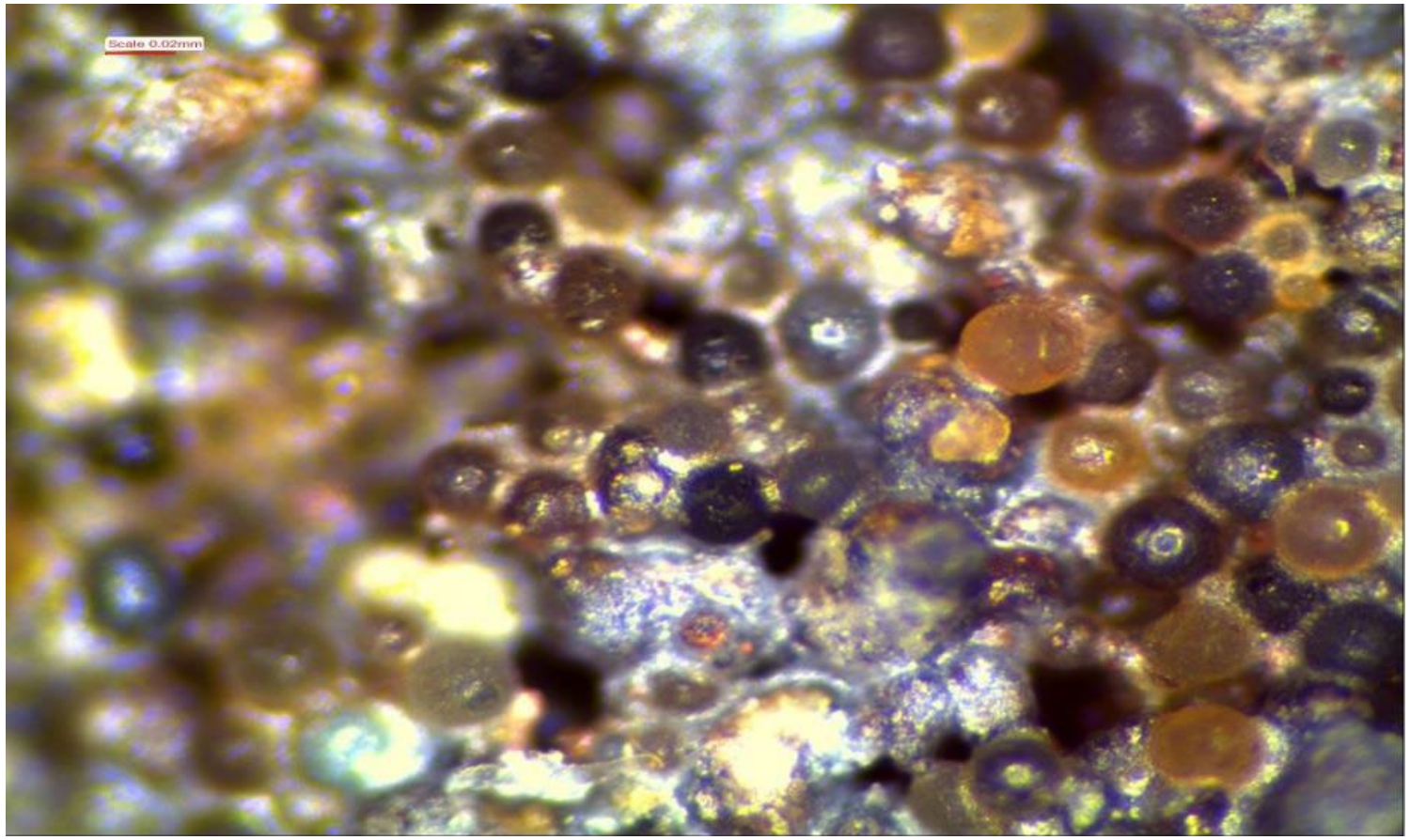
Storing

Energy is stored between an hour and up to two weeks with minimal losses.

Discharching

Cold air takes the heat and leads it through the system to adapt temperature and heat transfer media for the required process.

The Storage Material



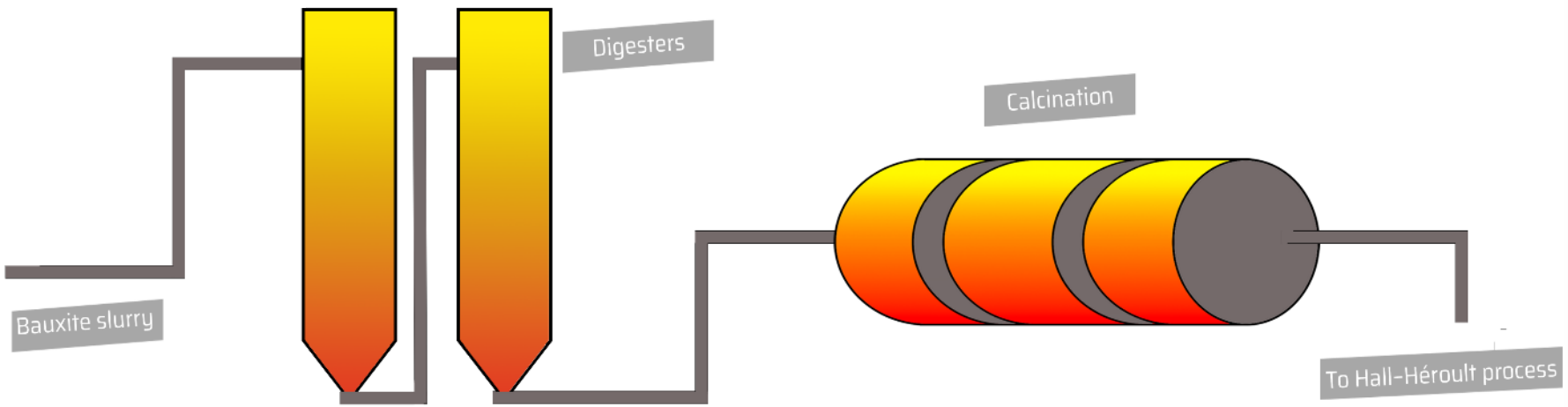
Invention on nanoscale

- Sustainable and wasted products
- Important characteristics: heat capacity, heat conducticity
- Mix of slags, additives and an anorganic binder
- Binder builds bridges between particles to distribute heat

Thermal Storages in the Aluminium Industry

Decarbonizing the Bayer process

Large Quantities of Process heat in Bayer Process (Scheme)



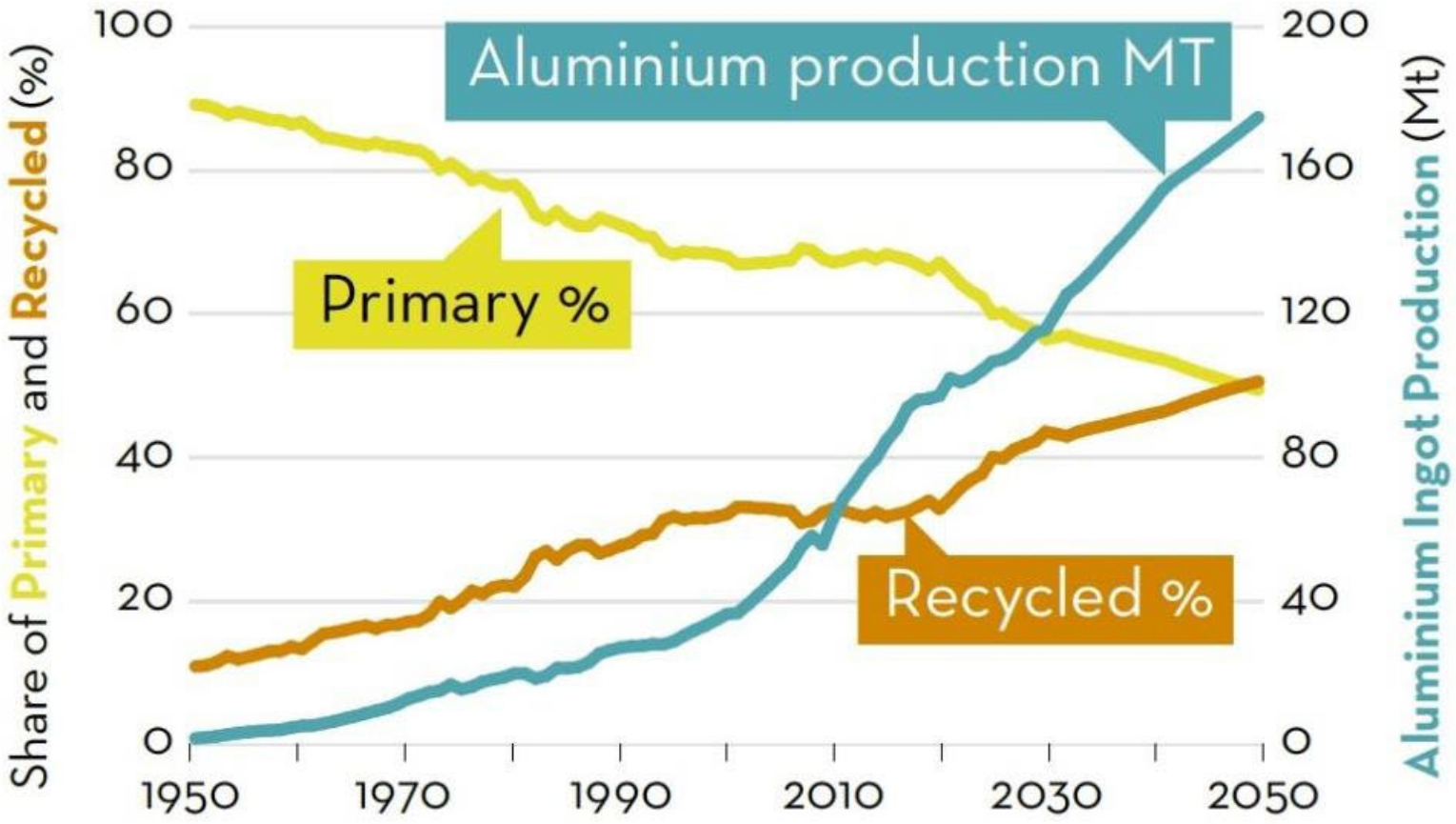
Steam
150°C – 250°C

Gas
800°C – 1,100°C

Replacing fossil fuels

- Steam generation from renewables + storage is low cost, low risk decarbonization
- For Aluminium oxide production (digesting, evaporating, product washing)
- Calcination is a possible application using hot air from the storage

Rise of Recycled Aluminium



Source: International Aluminium Institute, 2021.

Compelling cases

- Low energy demand
  - Primary: 15.7MWh / ton
  - Secondary: 0.8MWh / ton
  - Source
- Lower carbon emissions
  - Primary: 16t CO_2e / ton
  - Secondary: 0.5t CO_2e / ton
  - Source
- ~6% CAGR

Secondary Aluminium and Casting

Use cases

- Furnaces for smelting (low risk since medium-temperature)
- Waste heat can be reused to preheat ovens
- Scrap heating
- Hot Bending
- Batch processes are even more ideal for storages

Waste Heat in Aluminium

Primary

- Electrolysis waste heat (Hall-Héroult)
  - To generate power (ORC)
  - To re-use internally or externally
- 31 GWh/a waste heat from electrolysis for district heating: Trimet and Igony
- Calcination furnace off gas with heat exchanger (dep. on dust intensity)

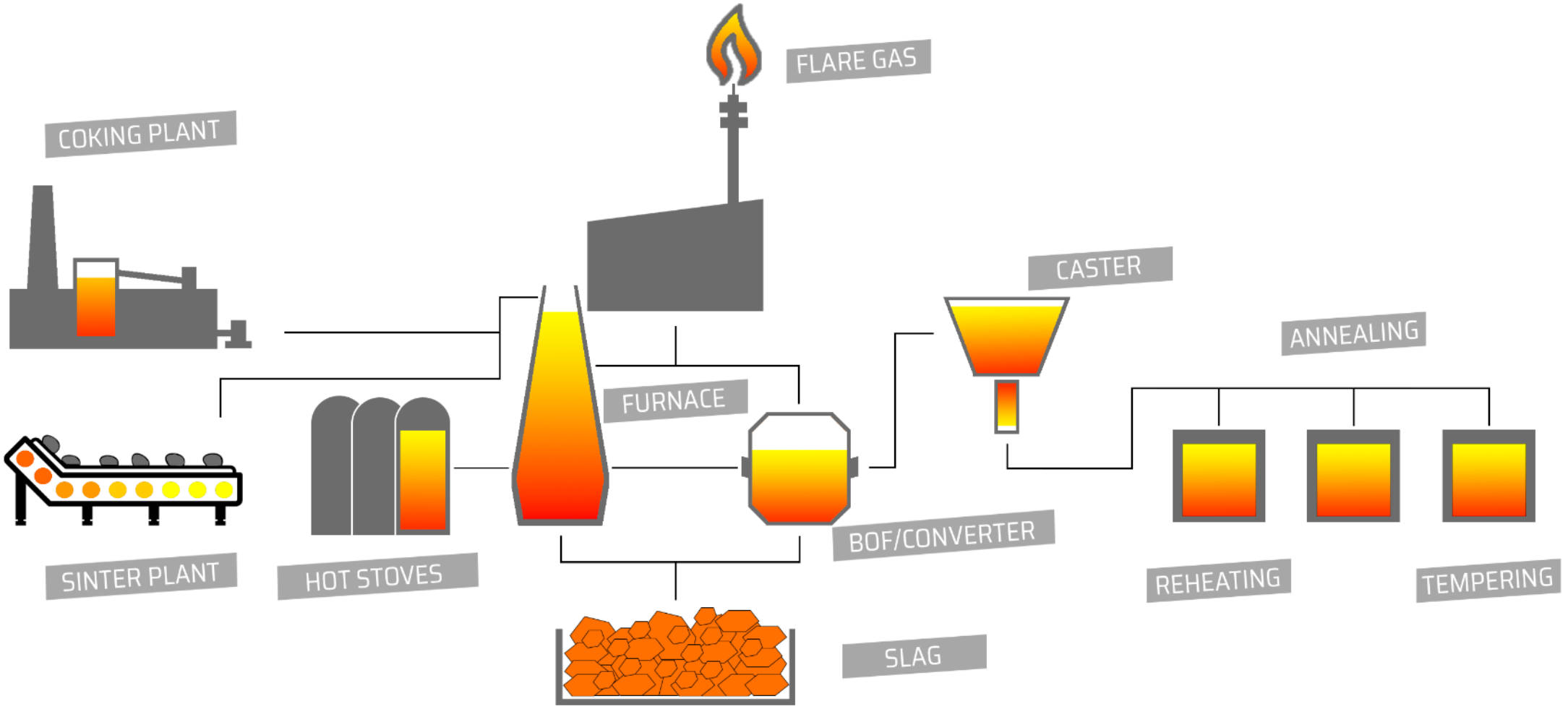
Secondary and Casting

- Many examples of using offgas for district heating, power generation
- Storages can be implemented to make the most of waste heat from batch processes

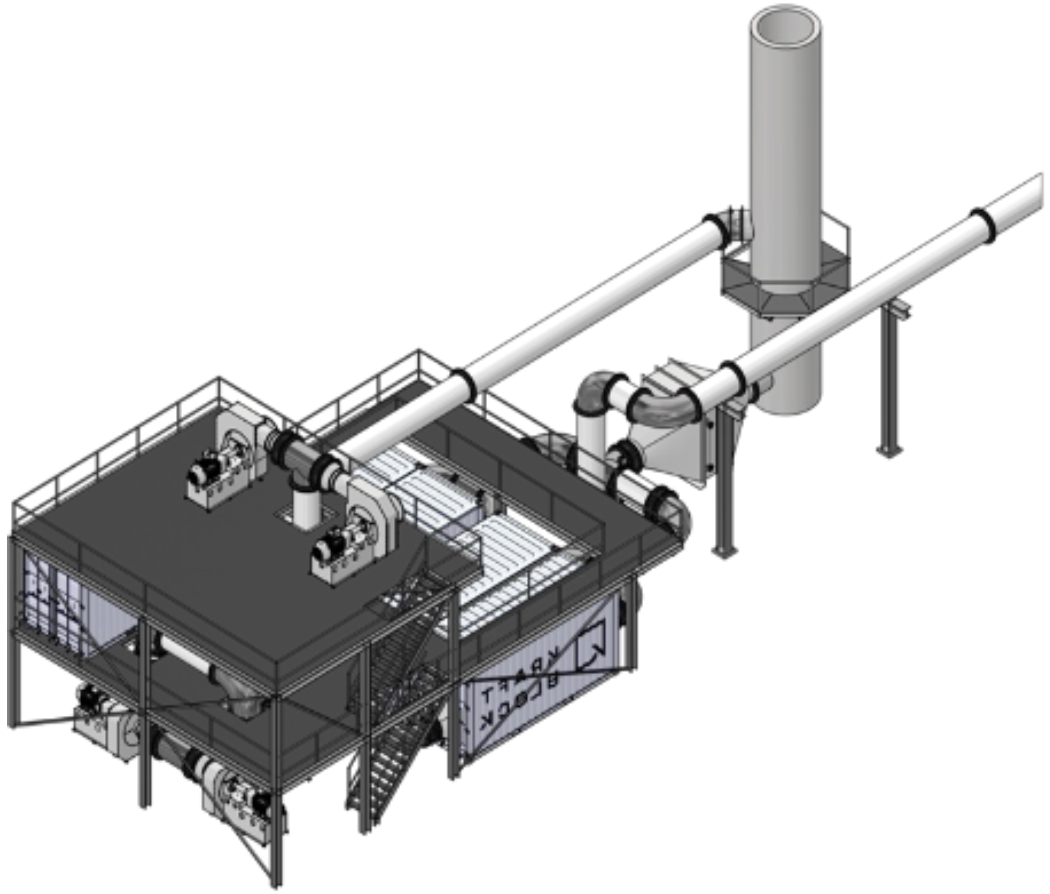
Abwärmestrom	Medium	Temperaturniveau
Abgase von Ofentypen mit Kaltluftbrenner	Abgas	900 – 1100 °C
Abgase von Ofentypen mit Rekuperator-Brenner	Abgas	400 – 600 °C
Abgase von Ofentypen mit Regenerator-Brenner	Abgas	180 – 300 °C
Abluft über Absaugung	Luft	40 – 80 °C
Gießprozesse	Gussstücke	50 – 300 °C

Thermal Storages in Steel Industry

Supporting Steel plant decarbonisation



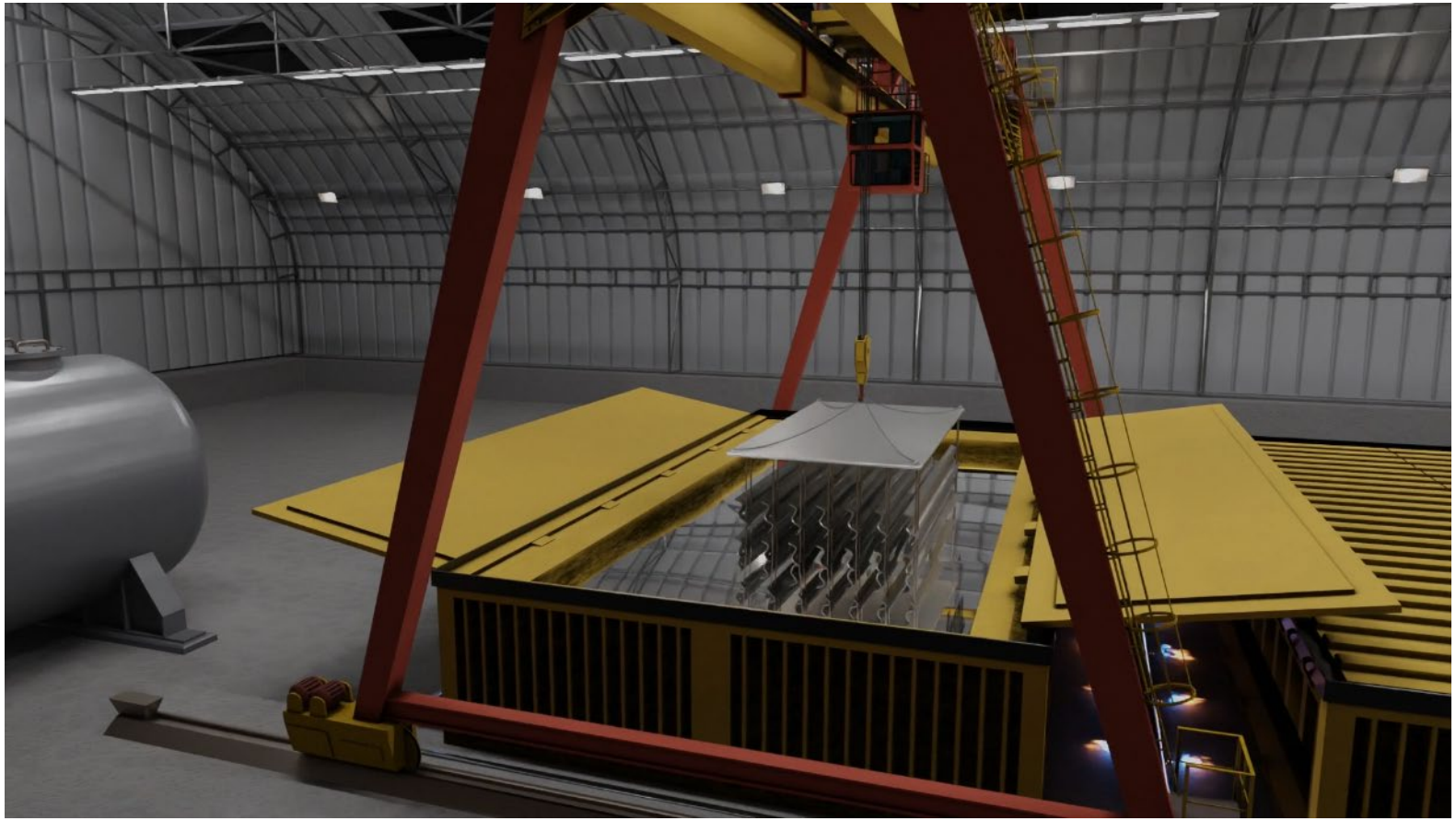
Retrofitting Sinter Plant



Sinter plant

- 20MWh capacity,
  Tmax: 500°C
- Utilisation in nodulizing drum
- Increasing throughput of sinter plant
- 20,000t of CO_2/a avoided
- Other project: flare gas

More Use Cases in the Steel industry

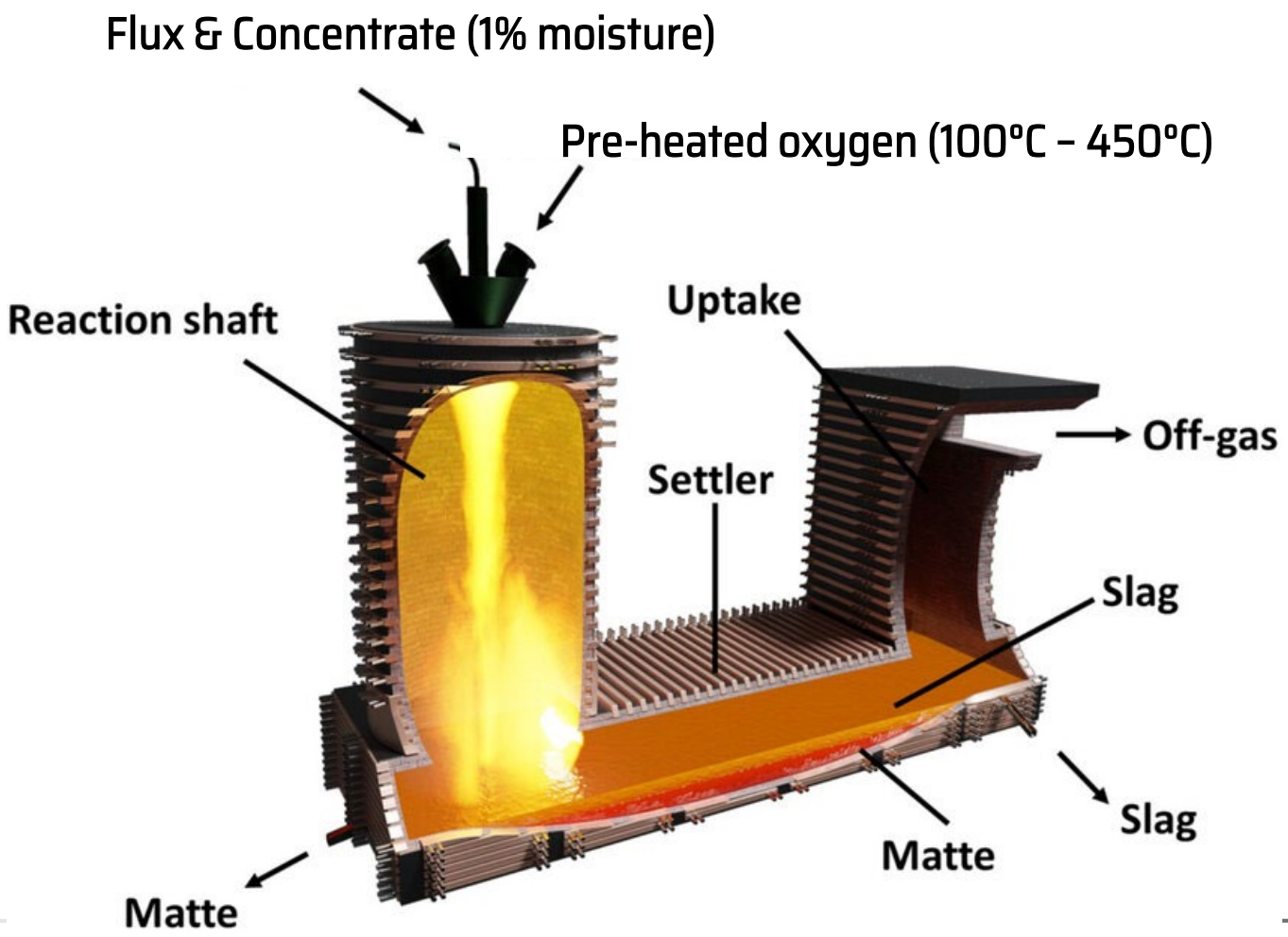


Diversity in Cases

- Zinc baths (600°C)
- Metal processing (Tempering, etc.)
- Pre-heating H_2
- External waste heat utilization

Thermal Storages in Copper Refining

Copper Refining



Use Cases

- Drying Furnace feed, which comes from Froth flotation
- Pre-Heating air / oxygen
- Supply heat to Slag Cleaning Furnace
- Pre-Heating rotary anode furnace

Closing Remarks

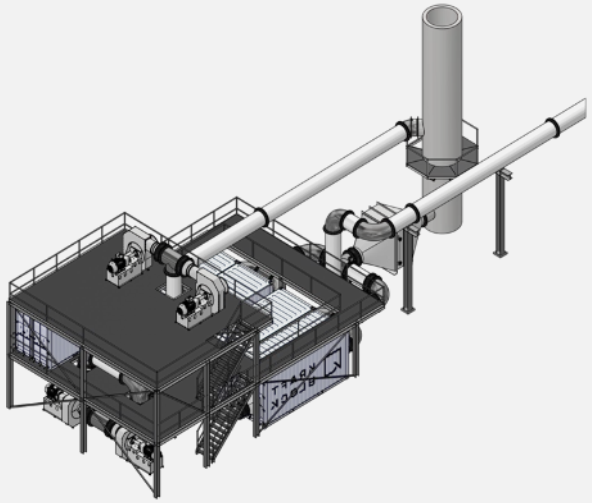
Innovation in Metals Industry

- Thermal Energy Storages can be high-temperature
- Waste Heat and Renewables can be linked with production through storage
- Access to cheap energy AND secure supply

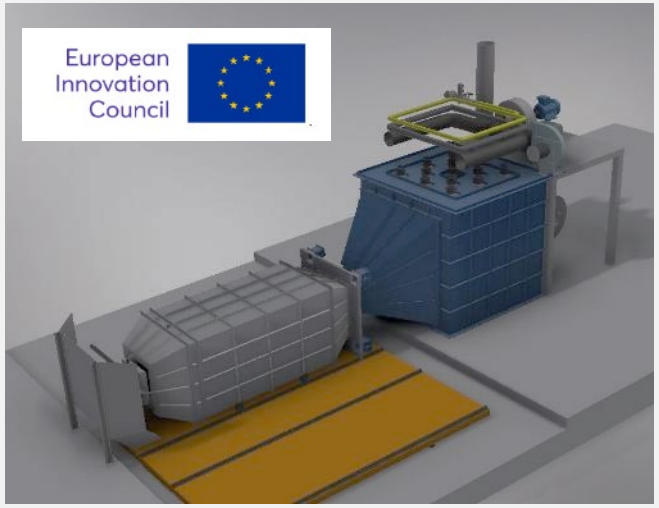
Kraftblock projects

Waste Heat Projects

- Ceramic industry
- Collecting over the week
- Preheating the batch process
- 330t of CO_2/a reduced



- Steel industry
- Collecting from sinter plant
- Reusing it in sinter mixing



- Using burned flare gases
- 100 GWh/a for reuse
- 9,300t of CO_2/a reduced

Volt Project – PepsiCo and Eneco

- Green power from **Eneco** is converted to 800°C heat
- Kraftblock system realizes conversion, storage and heat transfer to thermal oil
- Included is the worldwide largest commercial high-temperature storage (70 MWh respecteviely ~150MWh)
- Existing infrastructure is used, only gas-fired boiler is replaced

PEPSICO

Eneco

- 25MW boiler is ‚replaced'
- 4.5m m³ natural gas saved
- 8,500t of CO_2 avoided in first step (2 out of 5 modules)
- 98% of emissions are avoided when project is finished

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