



CIRCULAR THERMALSM

Industrial Decarbonization: The Waste Heat Recovery Opportunity

Armstrong International

- | Founded in 1900 in Michigan (USA)
- | Privately-owned and managed by the 5th generation of Armstrong and Bloss families;
- | 15 facilities globally, 3000+ employees
- | EMEA Headquarters in Belgium (1969)
 - Manufacturing units in Belgium, France & Italy
 - Thermal Engineers in Belgium, France, Italy, Germany, UK, the Netherlands & UAE
 - Represented in all other European countries
- | A Global Company
- | JV with Combitherm GmbH (Stuttgart)
 - Since 1972: oldest independent (family-owned) manufacturer of heat pumps in Germany

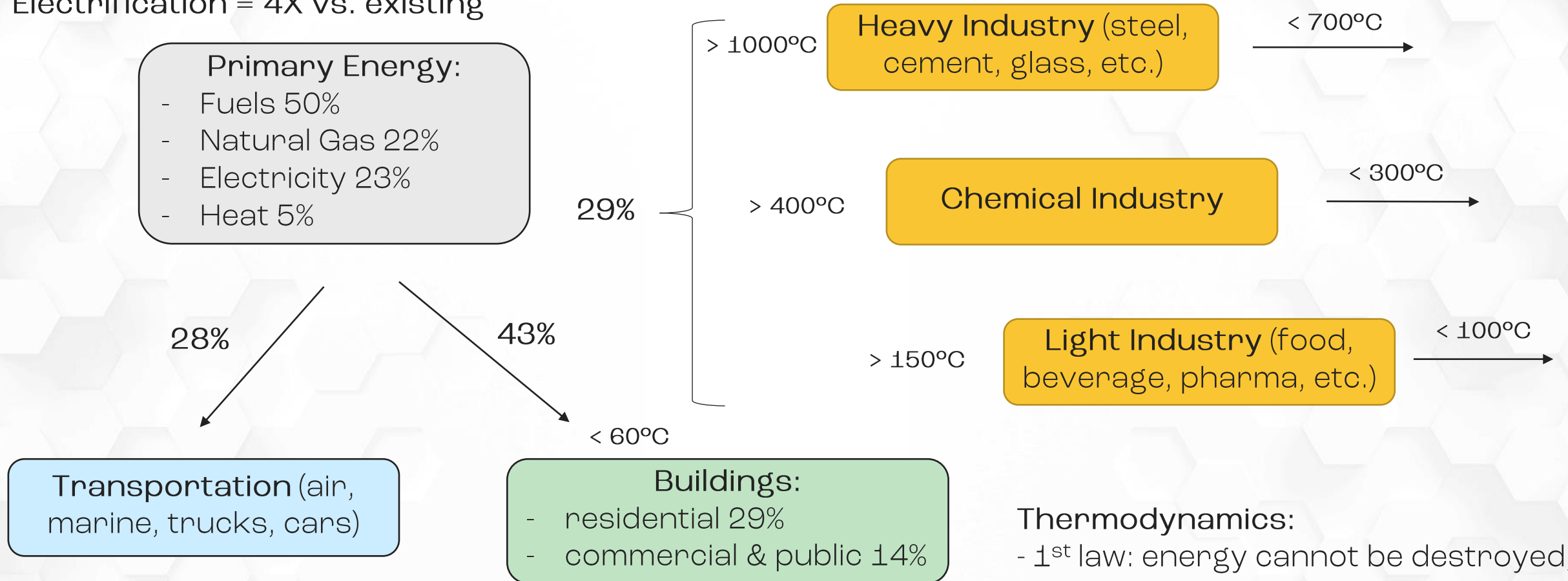


Current EU Energy System

Energy used = 1/3; wasted = 2/3

Electrification = 4X vs. existing

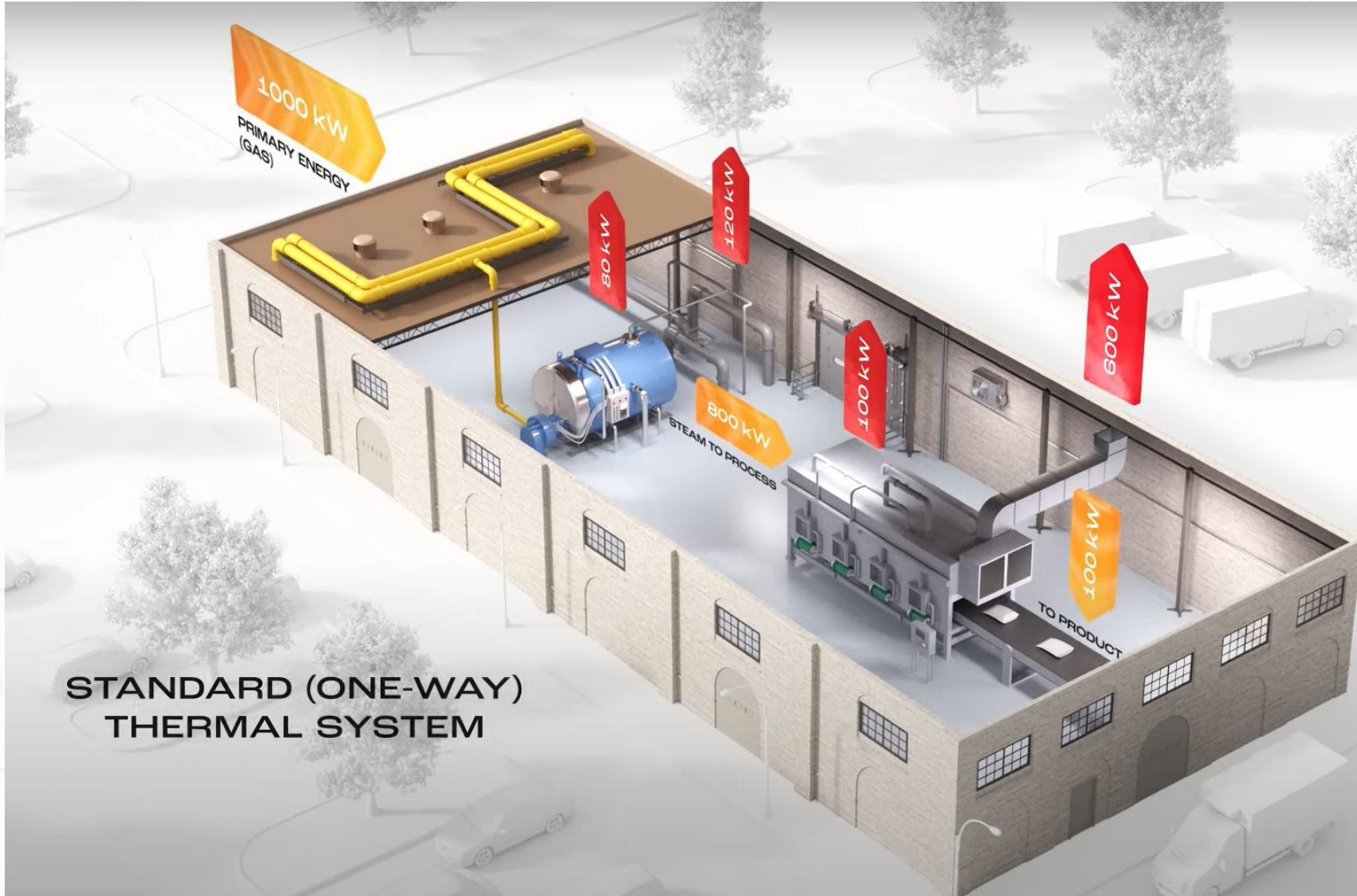
Waste Heat = 10% of primary energy, 30% of useful energy



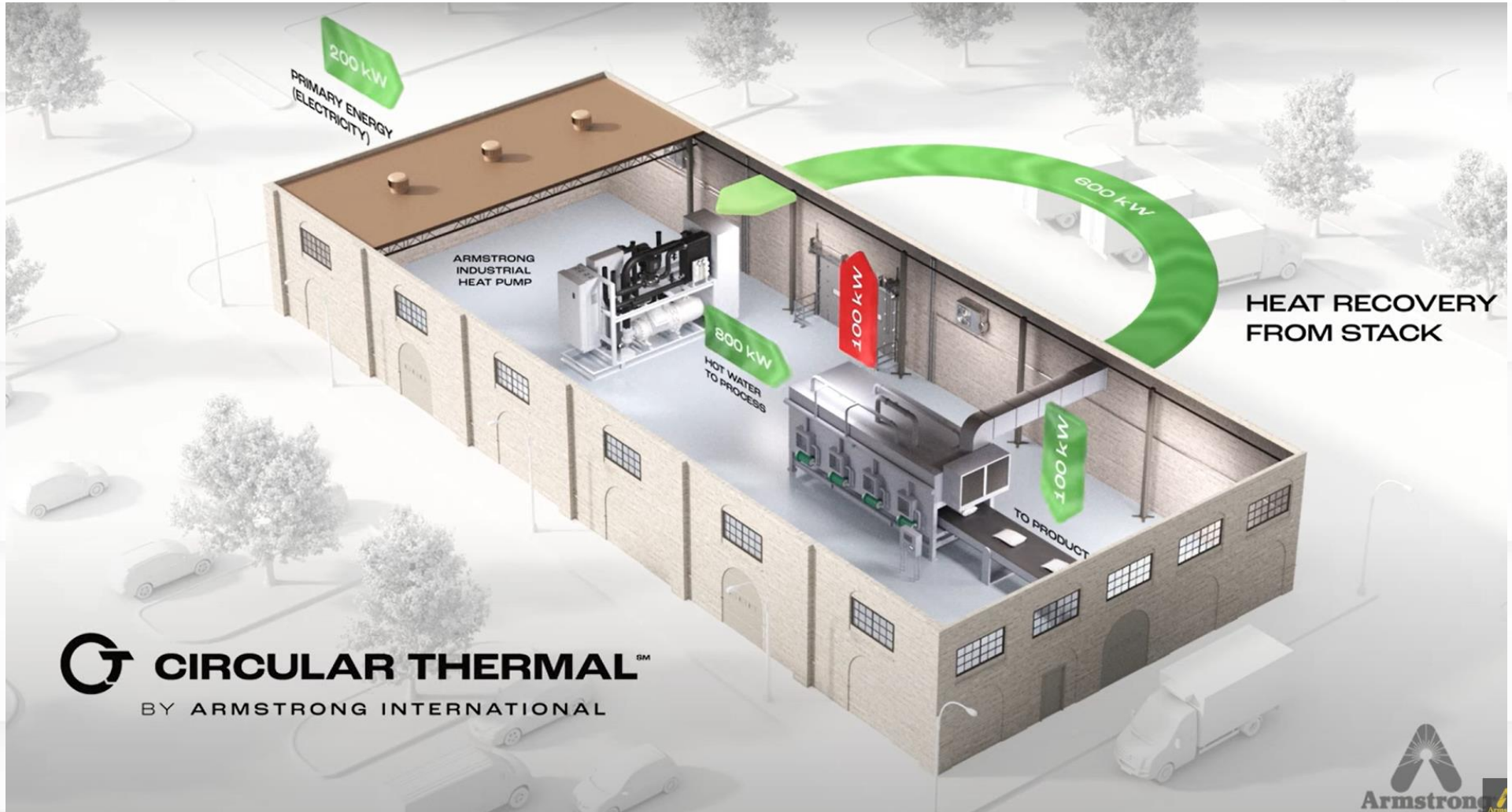
Thermodynamics:

- 1st law: energy cannot be destroyed, neither created
- 2nd law: when energy is used, it is degraded

Current «One-Way» Thermal System

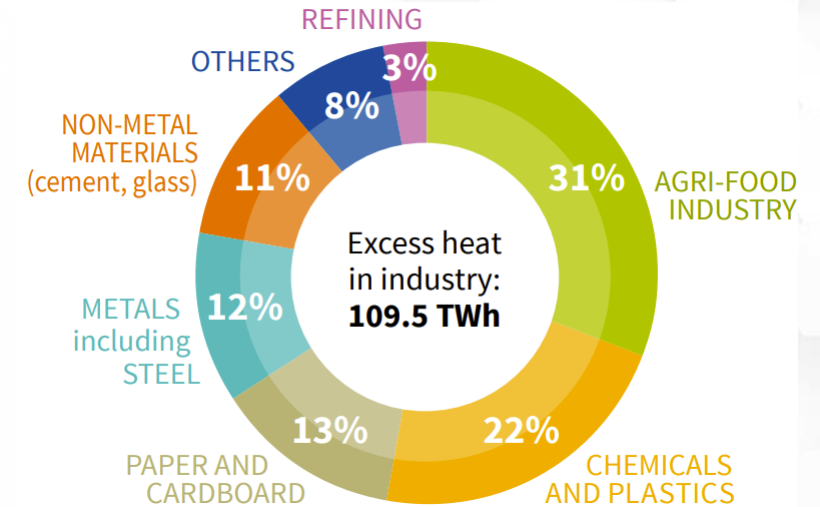


Circular ThermalSM System

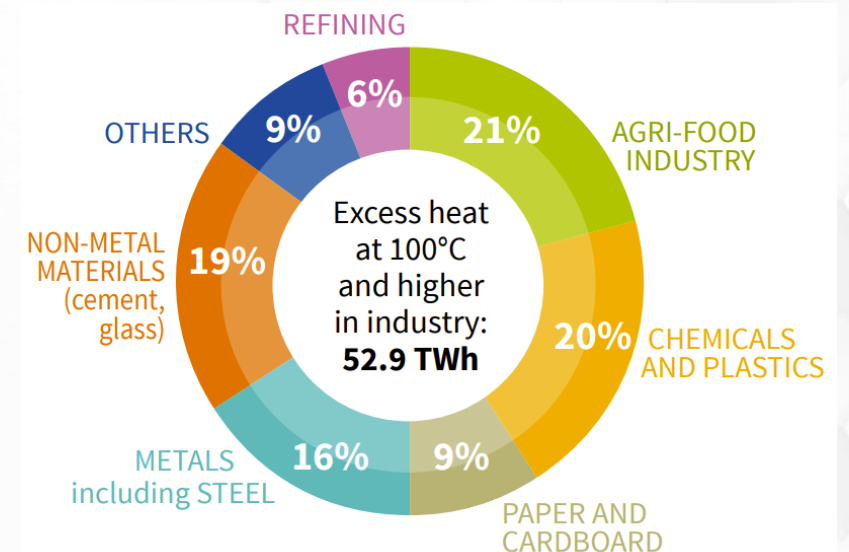


European Industrial Waste Heat potential

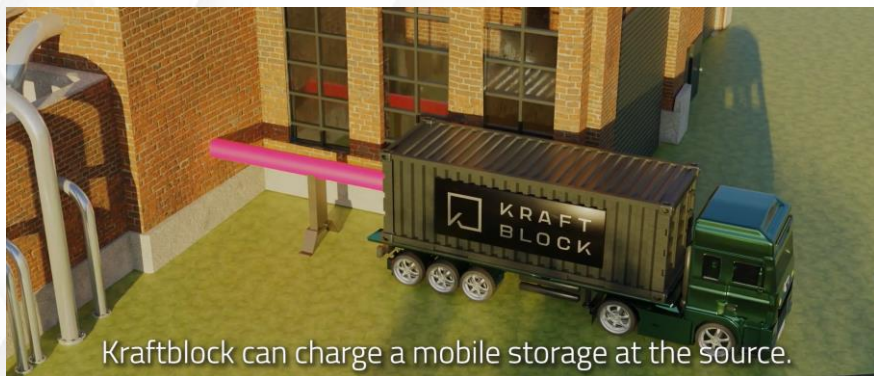
- | 1.000 Twh/year – half < 100°C (mainly Light Industry), half > 100°C (mainly Heavy Industry)
- | About 35% to 50% of current primary energy for Industry
- | 35% of current overall Natural Gas consumption = 10% of CO₂ emissions
- | Industrial Low-Grade Heat Recovery requires 100 GW of High-Temperature Heat Pumps
 - Only 1% already installed
 - 30.000 industrial plants
 - 150 Bn€ total investment in Circular ThermalSM systems



ADEME study for France – “Excess Heat” (2017)



Movable Solid Thermal Storage



Up to **1,300°C** temperature



PATENTED



Modular, scalable energy storage for 4 MWh up to 10,000 MWh



Outstanding **capacity** of up to **1.2 MWh/m³**



No rare earth materials - up to **85% recycled materials**

Thermal Integration of EU Energy System

-50% of current primary energy
Energy used = 2/3; wasted = 1/3?

Efficient Electrification =
2X vs. existing

Low-temperature
heat pumps

Transportation (air,
marine, trucks, cars)

District Heating
< 60°C

Buildings:
- residential
- commercial & public

Movable Thermal
Storage

> 1000°C

Heavy Industry (steel,
cement, glass, etc.)

< 700°C

Chemical Industry

< 300°C

Light Industry (food,
beverage, pharma, etc.)

< 100°C

Circular Heat
= 30% of primary
energy, >50% of
useful energy

Industrial
High-Temperature
Heat Pumps

Hydrogen Electrolyzers = 20% - 30% waste
heat at 60°C = 15% more industrial waste heat
(if 10 MT/year)

- District Heating
- High-Temperature district heating or
Industry (heat pumps)

Selling waste heat decreases hydrogen price

Industrial Waste Heat – The Political Opportunity

- | Waste Heat is a significant source of energy that is **free, local** and **decarbonized**
- | Contributes to both **EU Climate and Energy Autonomy Goals**
- | “Efficient electrification” **lowers the investment in upstream infrastructure** (renewables, grid, storage, transformers, etc.)
- | **Decreases energy costs** for companies – contributes to **industrial competitiveness**, without price increase of manufactured products
- | Companies are rational buyers, responding well to market signals
- | Invisible to most people – systems within industrial sites run by engineers
- | Impactful: 1 average factory = 1 500 houses
- | Deployment not delayed by permits (no safety risk – except if chosen refrigerant is less safe – or additional regulated environmental impact)
- | Industrial investment resulting into local job creation (equipment manufacturers, energy engineers and mechanical contractors)
- | A **positive narrative** for Decarbonization in general and heat pumps in particular

Industrial Waste Heat – possible Political Actions

- | Create **awareness** about the Waste Heat Opportunity among policy-makers (EU & Member States) and business decision-makers
 - Add industrial waste heat in REPowerEU (specific application of the “energy-efficiency first” principle)
- | Long-term framework giving **visibility** to business decision-makers
 - Innovators: all technology already at TRL9 (EU R&D projects since 2015)
 - Early Adopters: subsidies for pilot projects (currently available – EU Innovation Fund)
 - Early Majority: shift taxes from electricity to gas (2:1 ratio) from 2025
 - Late Majority: taxes on CO₂ and waste heat emissions (ETS2 from 2027, pollution directive)
 - Laggards: phase-out of natural gas boilers in the industry (from 2040)
 - Avoids stranded assets for industrial companies and **utilities** (overbuilt renewables & grid)
- | Develop a **protective legislative landscape** fulling enabling waste heat recovery technologies including the current PFAS and F-gas files
- | Mandate waste heat recovery from hydrogen electrolyzers
- | Movable thermal storage: create liquid market for waste heat PPAs (additional revenue stream for the heavy industry)



Armstrong provides intelligent system solutions that improve thermal utility performance, lower energy consumption, and reduce environmental emissions while providing an enjoyable experience.