Competing or Complementary? Electrification and Hydrogen for a Decarbonized European Industry

Policy-relevant findings from EU research community

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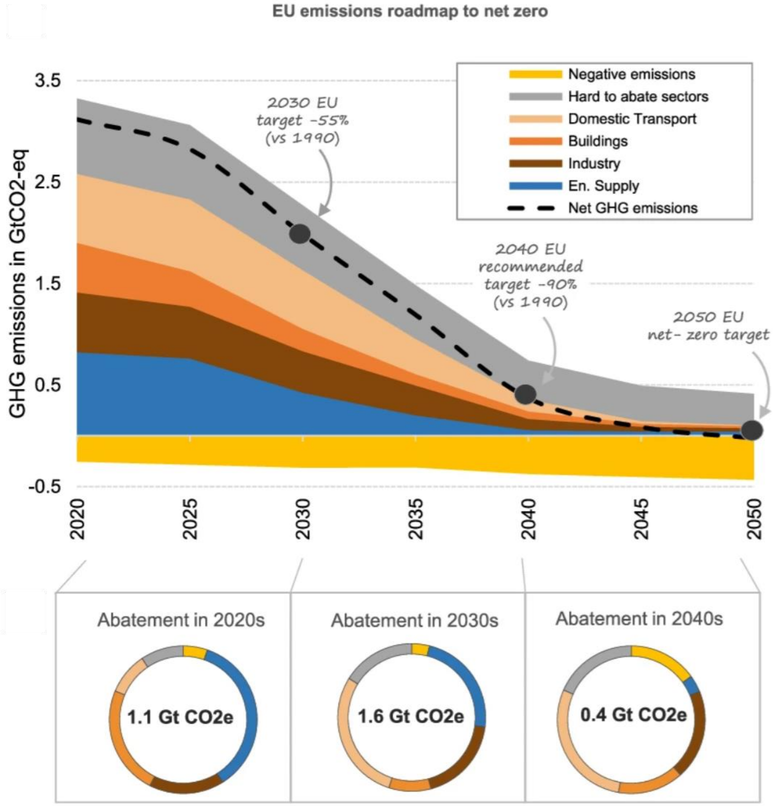
Presentation Structure

1. Hydrogen and Electrification in Europe’s Industrial Transformation
2. Industrial Energy and Emissions Challenge
3. Distinct Roles of Electrification and Hydrogen
4. Electrification: The Efficiency-First Pathway
5. Hydrogen: Where It Is Truly Essential
6. Infrastructure and Market Constraints
7. Policy Recommendations and R&I Priorities for a Balanced Transition

Hydrogen and Electrification in Europe's Industrial Transformation

Europe's industry is central to achieving climate neutrality by 2050



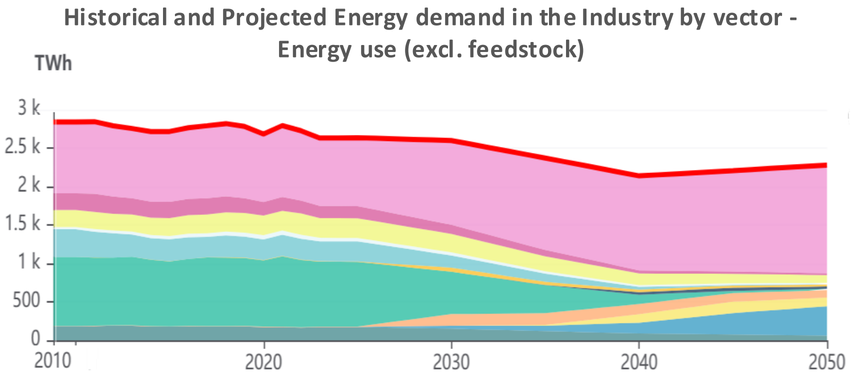
Source: European Commission. Impact Assessment Report. Securing our future Europe's 2040 climate target. SWD/2024/63 (2024)

Industrial energy use and processes remain a major source of CO_2 emissions

Industrial processes account for ~20% of EU GHG emissions

Energy intensive industries make up about the half of the energy consumption of EU industry

Electrification and hydrogen are key transition vectors



🟦 Hydrogen emerges as a new energy carrier from ~0 TWh (2020) to ~382 TWh (2050), mainly for feedstocks

🟪 Electricity demand increases by 60% for 30 years period (2020-2050)

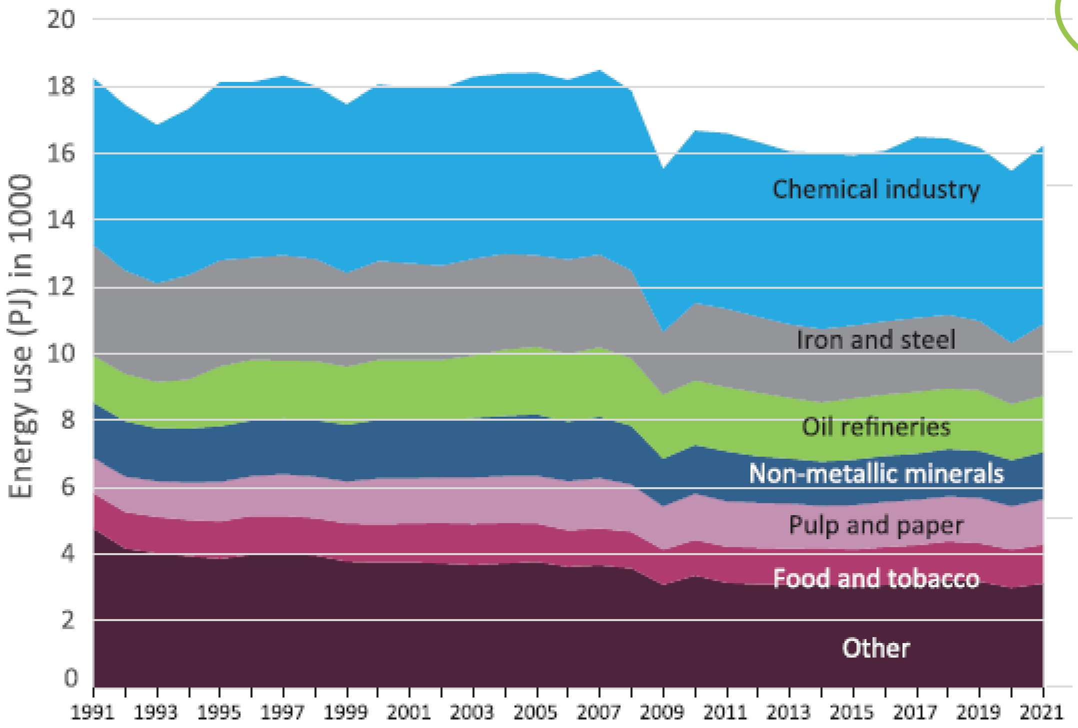
Source: Pathways Explorer, EU-27 based on European Commission's Impact Assessment (IA) scenario for the EU's 2040 climate target, 'balanced' pathway

Industrial Energy and Emissions Challenge

EU Industry consumes about 16000 PJ of energy annually
Most of this energy use is delivered by combustion of fossil fuels

Representative EU GHG Contribution

Energy Demand by Industrial Sectors



Source: EERA . The Role and Impact of Energy Efficiency in Decarbonising European Industry

Chemicals, 33%

Feedstock-intensive, gas- dependent, hardest to substitute molecules

Third largest with 5 % of EU GHG

Iron & Steel, 13%

Energy-intensive primary production; recycling already electrified

~25.5 % of industry ETS emissions

Non-metallic minerals / Cement, 9%

High-temperature kilns + process emissions from calcination

Second largest

Pulp and paper, 9%

Heat-dominated processes with ong waste-heat and biomass use

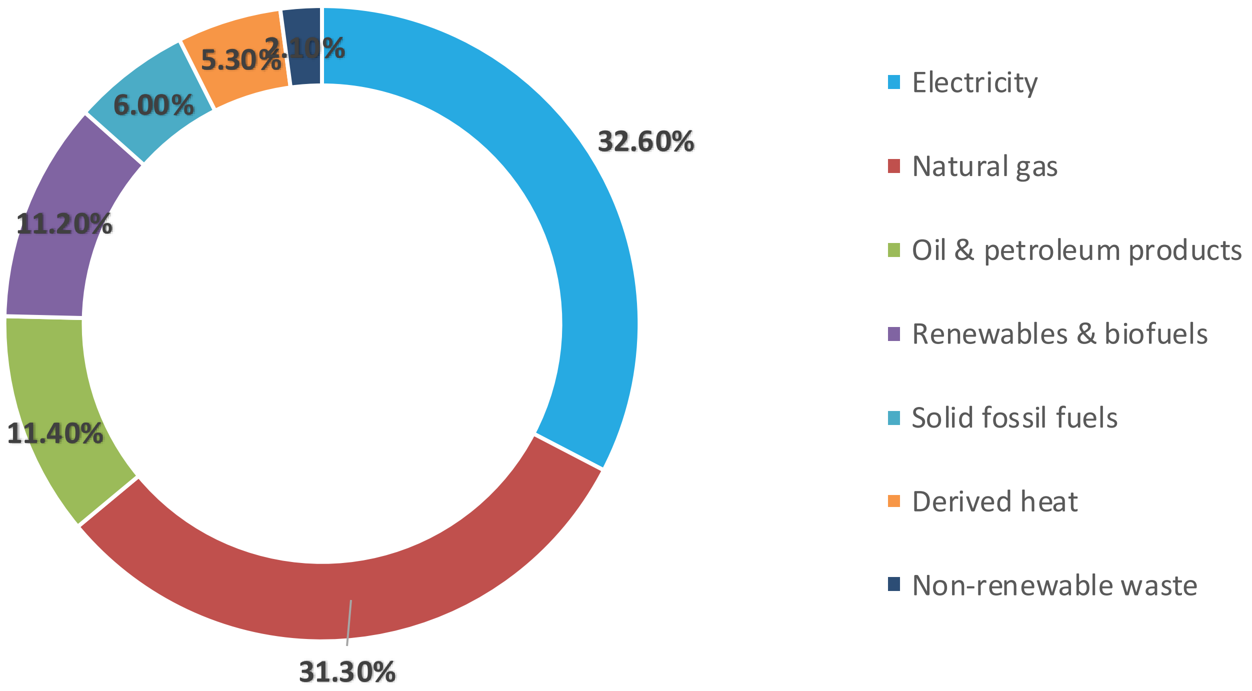
Agro-food industry,7%

Low-temperature process heat and drying; electrification-ready

Industrial Energy and Emissions Challenge

Electricity currently meets only one-third of the EU industry’s energy needs.

Final energy consumption in EU industry by energy carrier (2023 data):



Distinct Roles of Electrification and Hydrogen

Complementarity, not competition!

Electrification – Efficiency-First Pathway

- Direct and highly efficient substitution for industrial heat
- Highest-efficiency decarbonisation option across end-uses
- **Electric motors**: ~95% efficiency vs. ~30–35% for steam turbines, cutting conversion losses in mechanical drive
- **Industrial heat pumps**: COP 3–6, delivering 50–80% energy savings; could supply up to 37% of Europe's process heat demand (~730 TWh/year) and avoid ~146 Mt CO_2 annually
- **Commercially viable today below 100 °C** (e.g. dairies, breweries, paper mills) and rapidly advancing toward 200–250 °C for food, chemical and steel processes

Hydrogen as Feedstock – Non-Substitutable Role

- Essential where molecules matter, not just energy
- **Key applications**:
  - ➢ Ammonia: ~90% of global hydrogen demand today
  - ➢ Methanol & refining: process-integrated hydrogen use
  - ➢ Steel (DRI): hydrogen enables near-zero-carbon primary steelmaking
- No direct electrification alternative for these chemical transformations

Hydrogen as Energy Carrier – Targeted Use

- Enables very high-temperature processes (>800–1,000 °C):
- Steel, glass, cement (as an example)
- Provides energy storage and system flexibility > Seasonal storage and balancing variable renewables
- Efficiency reality:
  - ➢ Green hydrogen: ~65–70% electrolysis efficiency (LHV)
  - ➢ Lower system efficiency than direct electrification, but strategic where electrification is infeasible

Electrification: The Efficiency-First Pathway

AHEAD: ADVANCED HEAT PUMP DEMONSTRATOR

- **Heat pump based steam production demonstrator** at 11 bar (184 °C)
- integrated at a production site of Takeda in Vienna
- official commissioning in September 2025
- scientific monitoring and optimisation for more than 4000 h planned
- reduction of CO_2 emissions by ca. 80%
- almost CO_2 free steam generation for >7 months a year
- high multiplication potential in other sectors (food & chemical industry)

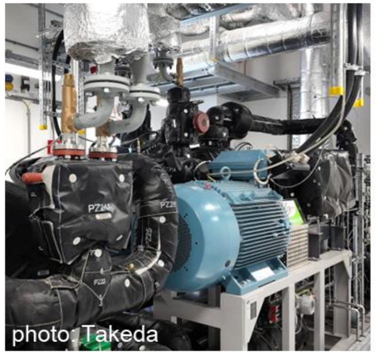


photo: Takeda

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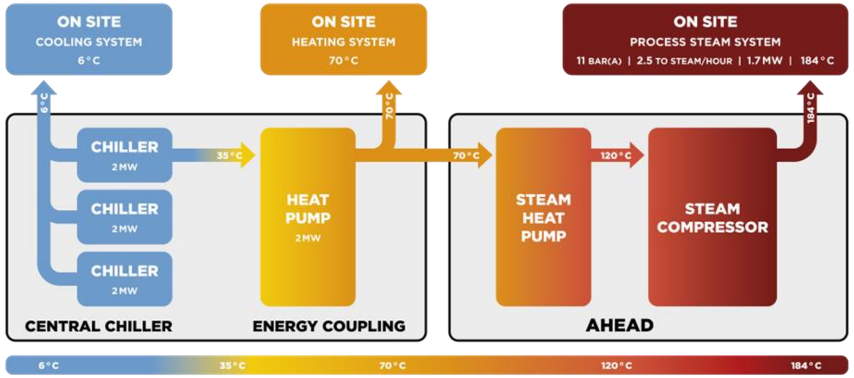

ON SITE
COOLING SYSTEM
6 °C

ON SITE
HEATING SYSTEM
70 °C

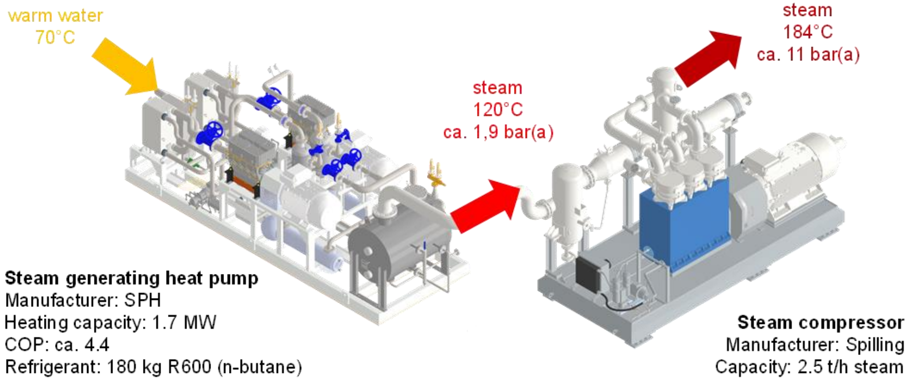
ON SITE
PROCESS STEAM SYSTEM
11 BAR(A) | 2.5 TO STEAM/HOUR | 1.7 MW | 184 °C

CHILLER 2 MW
CHILLER 2 MW
CHILLER 2 MW
CENTRAL CHILLER

HEAT PUMP 2 MW
ENERGY COUPLING

STEAM HEAT PUMP
STEAM COMPRESSOR
AHEAD

6 °C → 35 °C → 70 °C → 120 °C → 184 °C


warm water
70°C

steam
120°C
ca. 1,9 bar(a)

steam
184°C
ca. 11 bar(a)

Steam generating heat pump
Manufacturer: SPH
Heating capacity: 1.7 MW
COP: ca. 4.4
Refrigerant: 180 kg R600 (n-butane)

Steam compressor
Manufacturer: Spilling
Capacity: 2.5 t/h steam

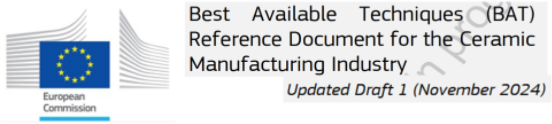
This project is supported with the funds from the Climate and Energy Fund and implemented in the framework of the RTI-initiative "Flagship region Energy"

Source: V. Wilk, J. Riedl, F. Hubmann, V. Sulzgruber, R. Jentsch, S. Knöttner, B. Mauel, M. Pölzl, B. Windholz, G. Drexler-Schmid

Electrification: The Efficiency-First Pathway

GREENBRICKS

- **Industrial-Scale Carbon-Neutral Brick Factory** at Wienerberger plant Uttendorf/ Austria, targeting 88% CO_2 reduction and 30% decrease in primary energy demand (TRL 8).
- **Innovative Electric Tunnel Kiln** with high-temperature (up to 950°C) and advanced digital tools for virtual planning and thermal-process analysis.
- **24-Month Conversion Completed (Nov 28, 2024):** 100% renewable electricity for the e-kiln, 22 electric heating zones, test production of 270 tons/day ▶ reduction targets achieved.
- **Carbon-Neutral Clay Blends** developed using diatomite additives, validated at both lab and industrial scale; supported by new sawdust processing plant for premium insulated bricks.
- **Thermal Network Optimization:** Expansion of drying tunnel, heat pump commissioning, scrubber integration, and Digital Twin deployment for predictive control.
- **Modernized Infrastructure:** AGV-based brick transport, upgraded electrical and clay-preparation systems, positioning GreenBricks as a global energy-efficient benchmark.
- **Replicability:** Heat-recovery concept, e-kiln, and clay formulations ready for adoption in 5+ plants across 3 countries; new demos for roofing tiles and facing bricks in UK and Germany.
- **Industry Recognition:** Received “Energie-Star 2024” award and contributed to updating the EU BAT reference document for the Ceramic Manufacturing Industry .



European Commission

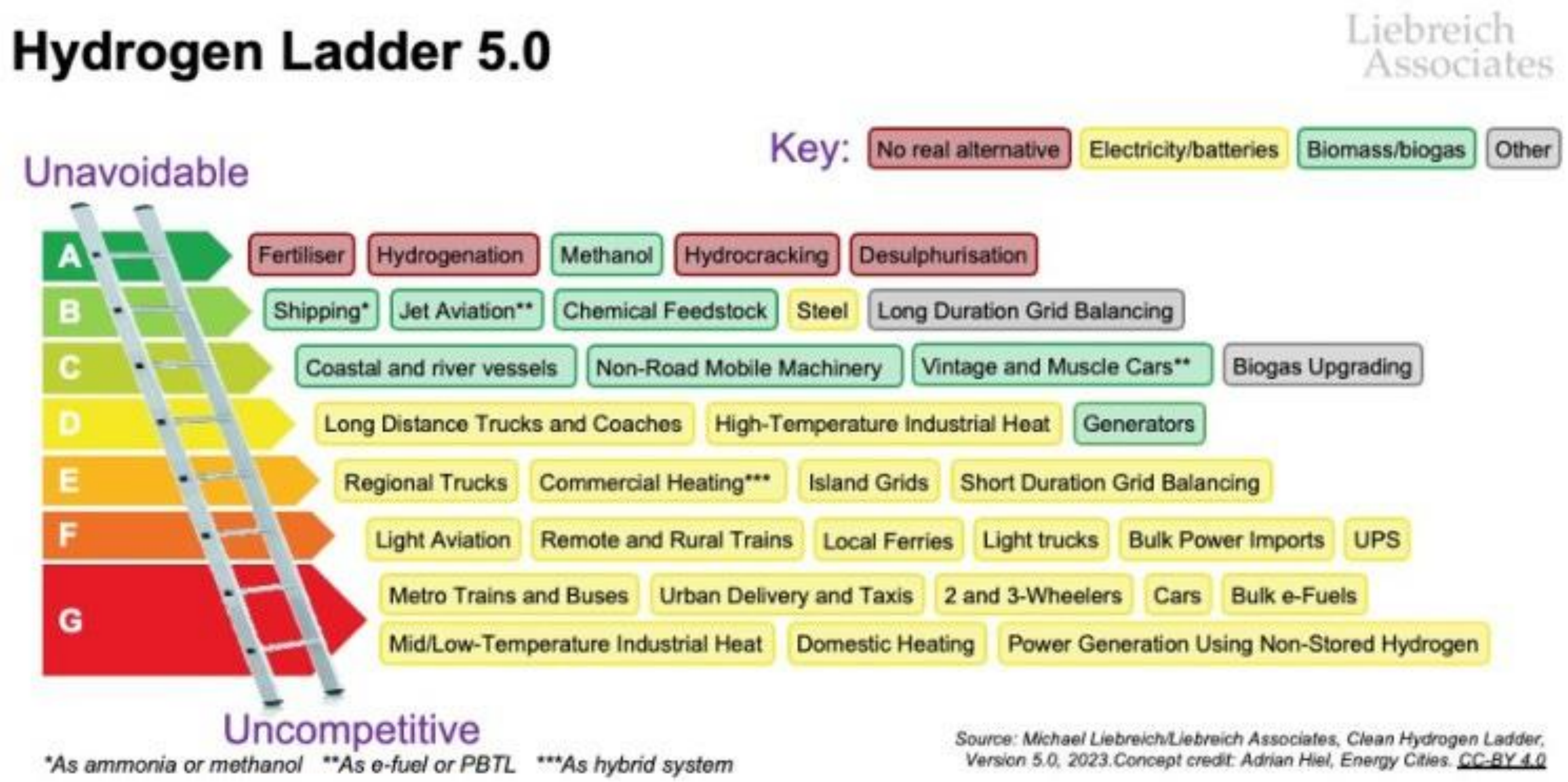
Best Available Techniques (BAT) Reference Document for the Ceramic Manufacturing Industry

Updated Draft 1 (November 2024)

Contact: Gerwin.Drexler-Schmid@ait.ac.at, Tilman.Barz@ait.ac.at

Hydrogen: Where It Is Truly Essential

Industry: (1) Feedstock & DRI, (2) long duration grid balancing, (3) high temperature industrial heat



*As ammonia or methanol **As e-fuel or PBTL ***As hybrid system

Source: Michael Liebreich/Liebreich Associates, Clean Hydrogen Ladder, Version 5.0, 2023.Concept credit: Adrian Hiel, Energy Cities. CC-BY 4.0

Source: Michael Liebreich

Hydrogen: Where It Is Truly Essential

Use Cases

Hydrogen as an Industrial Feedstock & Reduction Agent in an Integrated Industrial Cluster- Salzgitter Cluster (Germany)

- Used primarily for**: Iron and steel production as a reduction agent** (Direct Reduced Iron, DRI)
- Industrial transformation through the SALCOS® programme, combining hydrogen reduction and electric arc furnaces
- Supported by dedicated hydrogen pipelines, salt cavern storage in Northern Germany (e.g. Etzel region)
- **Stepwise transition pathway**: Natural-gas-based DRI as an intermediate step, transitioning to pure hydrogen DRI
- Renewable electricity supply from onshore and offshore wind linked to electrolysis

- Target CO_2 reduction: > 2 Mt CO_2/year (full SALCOS® deployment)
- Hydrogen demand: up to ~100,000 tonnes H_2/year (full H_2-DRI phase, post-2035)
- Steelmaking route: Blast furnace → NG-DRI → H_2-DRI + EAF
- Electric Arc Furnaces: Core technology for final steelmaking (already electrified)
- Infrastructure: Connection to German H_2 core network (H_2-Kernnetz)
- Storage: Access to salt cavern hydrogen storage in Northern Germany (Etzel region)
- Renewable supply: Onshore + offshore wind–linked electrolysis

Long-Term Hydrogen Storage in Salt Caverns – HyStock (Netherlands)

- Large-scale renewable and low-carbon hydrogen produced in and around the Port of Rotterdam
- Used primarily for: Chemical feedstocks (ammonia, methanol, refining)
- and Industrial transformation (incl. steel value chains)
- Supported by Dedicated hydrogen pipelines, Salt cavern storage
- Import terminals (ammonia, methanol, LOHCs)
- Offshore wind–linked electrolysis
- Caverns already used for natural gas storage
- Being converted and tested for pure hydrogen storage
- Integrated into the planned Dutch hydrogen backbone

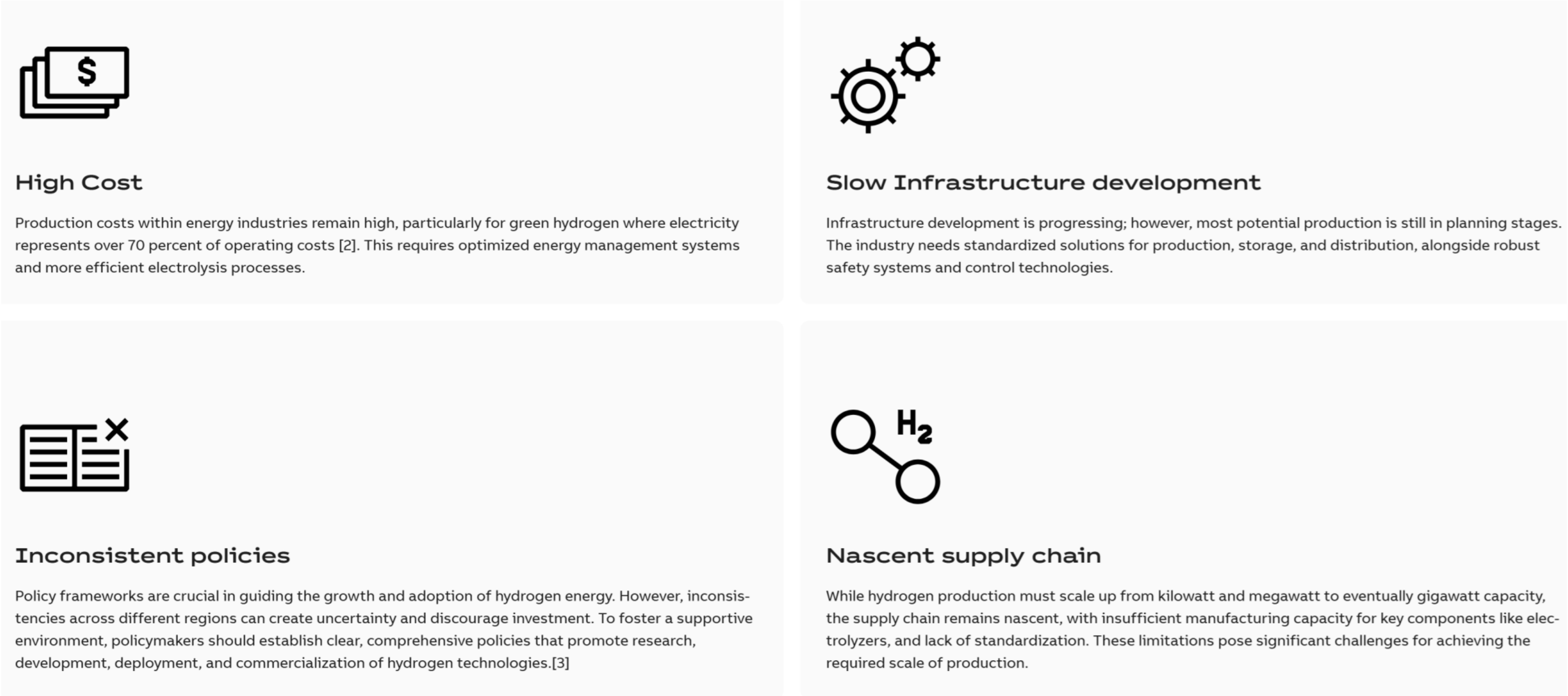
- Location: Zuidwending salt caverns, Northern Netherlands

Operator: Gasunie / EnergyStock

- 6 salt caverns suitable for hydrogen
- ~216 GWh of hydrogen storage capacity
- Storage pressure: up to ~300 bar
- Designed for seasonal storage (months, not hours or days)

Source: Salcos Program & Hystock

Infrastructure and Market Constraints of Green Hydrogen



High Cost

Production costs within energy industries remain high, particularly for green hydrogen where electricity represents over 70 percent of operating costs [2]. This requires optimized energy management systems and more efficient electrolysis processes.

Slow Infrastructure development

Infrastructure development is progressing; however, most potential production is still in planning stages. The industry needs standardized solutions for production, storage, and distribution, alongside robust safety systems and control technologies.

Inconsistent policies

Policy frameworks are crucial in guiding the growth and adoption of hydrogen energy. However, inconsistencies across different regions can create uncertainty and discourage investment. To foster a supportive environment, policymakers should establish clear, comprehensive policies that promote research, development, deployment, and commercialization of hydrogen technologies.[3]

Nascent supply chain

While hydrogen production must scale up from kilowatt and megawatt to eventually gigawatt capacity, the supply chain remains nascent, with insufficient manufacturing capacity for key components like electrolyzers, and lack of standardization. These limitations pose significant challenges for achieving the required scale of production.

Risk identified : **policy ambition outpacing market readiness**

Source: ABB

Policy Recommendations

Adopt an electrification-first and efficiency-first principle for industry

Make direct electrification and energy efficiency the default option wherever technically and economically Viable.

Ensure access to affordable, low-carbon electricity for industrial consumers

Treat electricity price and availability as a core industrial competitiveness policy.

Accelerate grid expansion and system flexibility as industrial infrastructure

Fast-track grids, connections, storage, and demand-side flexibility to remove the main bottleneck to electrification

Prioritise hydrogen for non-substitutable industrial uses

Focus hydrogen on feedstocks, reduction processes (e.g. steel DRI), selected high-temperature uses, and long-duration storage

Condition hydrogen support on system efficiency and low-carbon electricity sourcing

Tie public support for hydrogen to demonstrable system-level emissions and efficiency benefits.

Avoid broad hydrogen mandates where electrification or efficiency is superior

Prevent inefficient and high-cost hydrogen deployment in buildings heat, road transport, and generic process heat.

Deploy targeted de-risking instruments for first-of-a-kind industrial projects

Use CfDs, Innovation Fund support, and Hydrogen Bank-type auctions focused on real industrial offtakers.
.

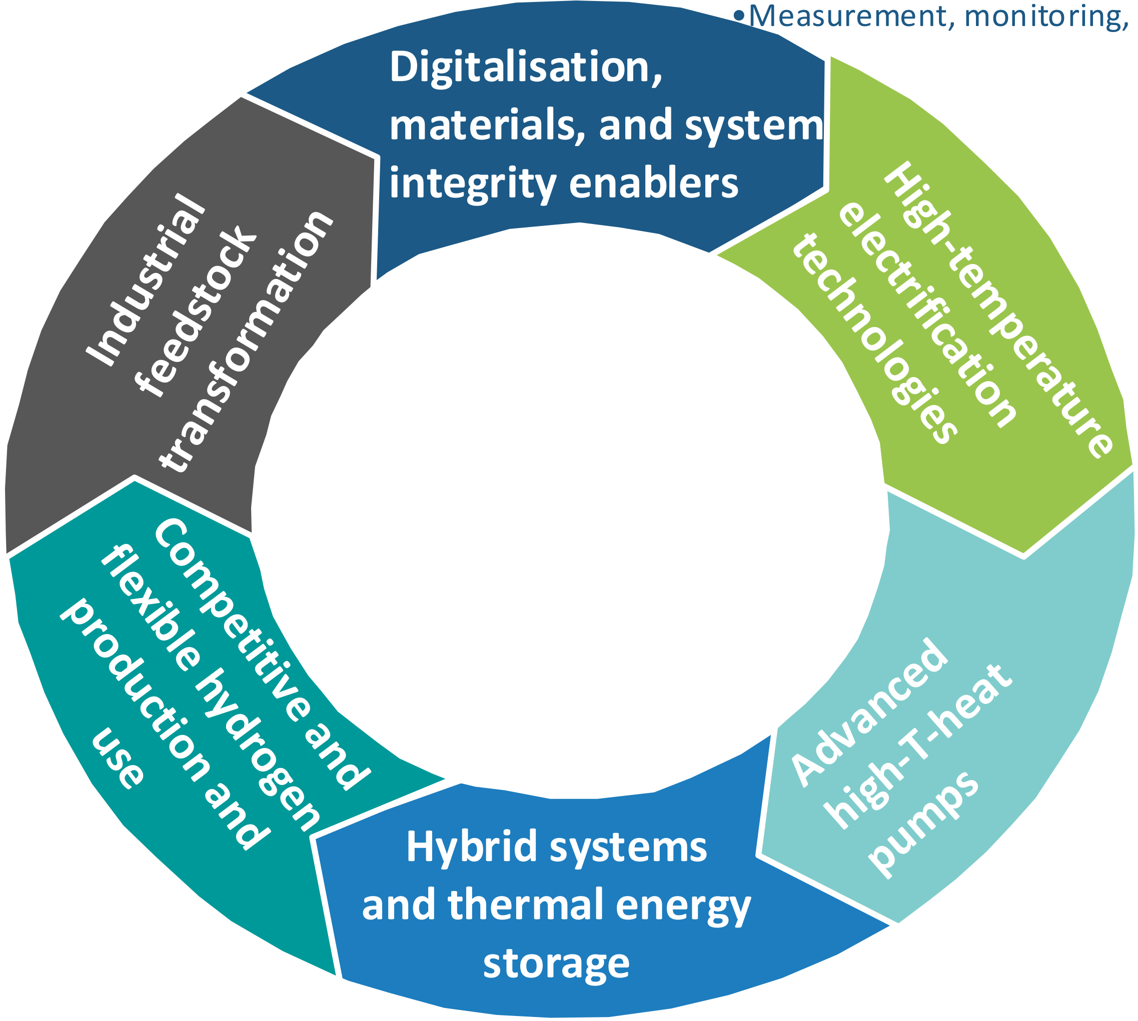
Enable pragmatic transition pathways in hard-to-abate sectors

Support stepwise transitions (e.g. NG-DRI to H_2-DRI, hybrid systems) without locking in fossil dependence.

Promote industrial clustering, skills, and standards as enabling conditions

Develop regional clusters with co-located demand and supply, harmonised safety rules, and dedicated workforce training.

R&I Priorities



Digitalisation, materials, and system integrity enablers

- Digital twins, AI-driven optimisation, system monitoring
- Advanced materials (power electronics, HTHP components, hydrogen-compatible materials)
- Measurement, monitoring, verification (MRV), safety, and standards

High-temperature electrification technologies

- Resistive, inductive, microwave heating
- Multi-MW scale, brownfield retrofitability
- Reliability for continuous industrial operation

Advanced high-T-heat pumps

- Push delivery temperatures beyond today's limits
- Improve performance at high temperature lift
- Unlock large-scale waste heat recovery

Hybrid systems and thermal energy storage

Bridge between technology and system reality.

Competitive and flexible hydrogen production and use

- Efficient, flexible electrolysers
- Hydrogen use aligned with system efficiency
- Integration with storage and infrastructure

Industrial feedstock transformation

- Hydrogen-based DRI in steel
- Green feedstocks for chemicals and refining
- Process redesign to reduce overall energy demand

THANK YOU FOR YOUR ATTENTION!

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