Competing or Complementary?
Electrification and Hydrogen for a Decarbonized European Industry
Policy-relevant findings from EU research community

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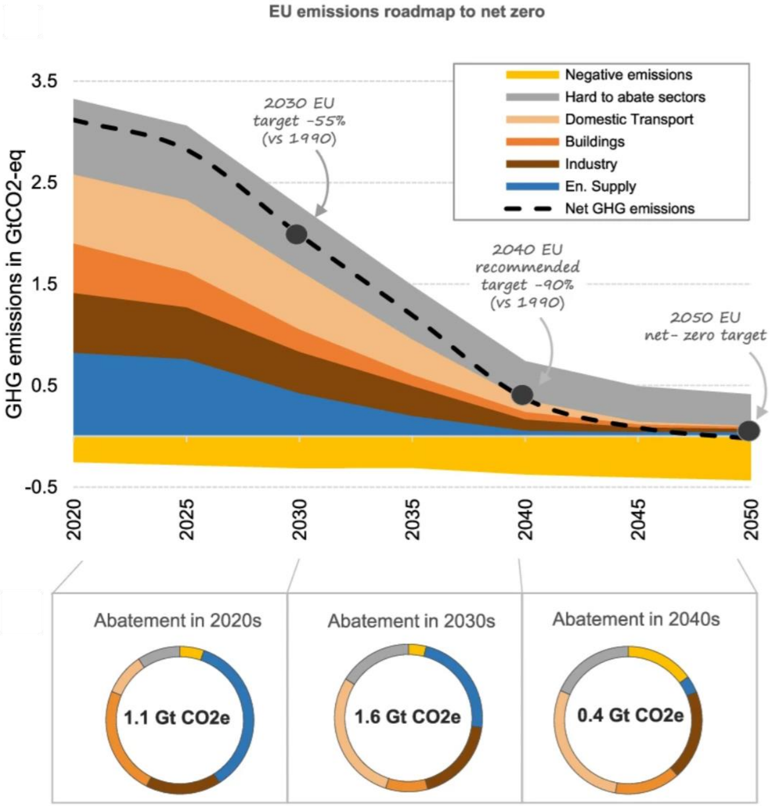
EERA European Energy Research Alliance

Presentation Structure

Hydrogen and Electrification in Europe's Industrial Transformation

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

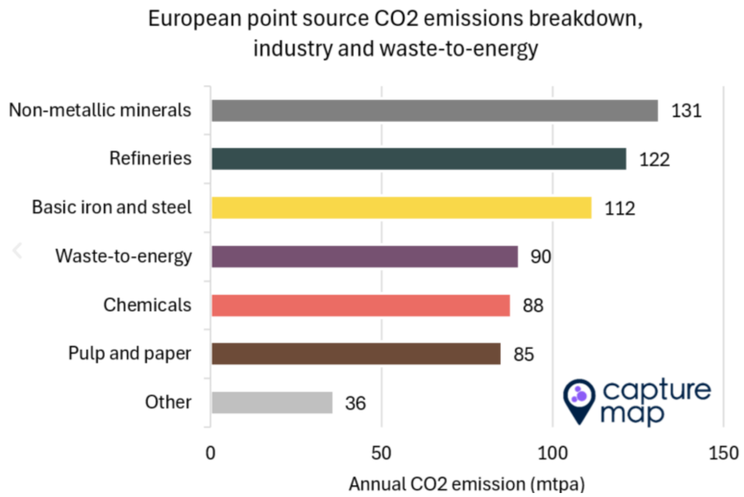


Source: European Commission. Impact Assessment Report. Securing our future Europe's 2040 climate target. SWD/2024/63 (2024)

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

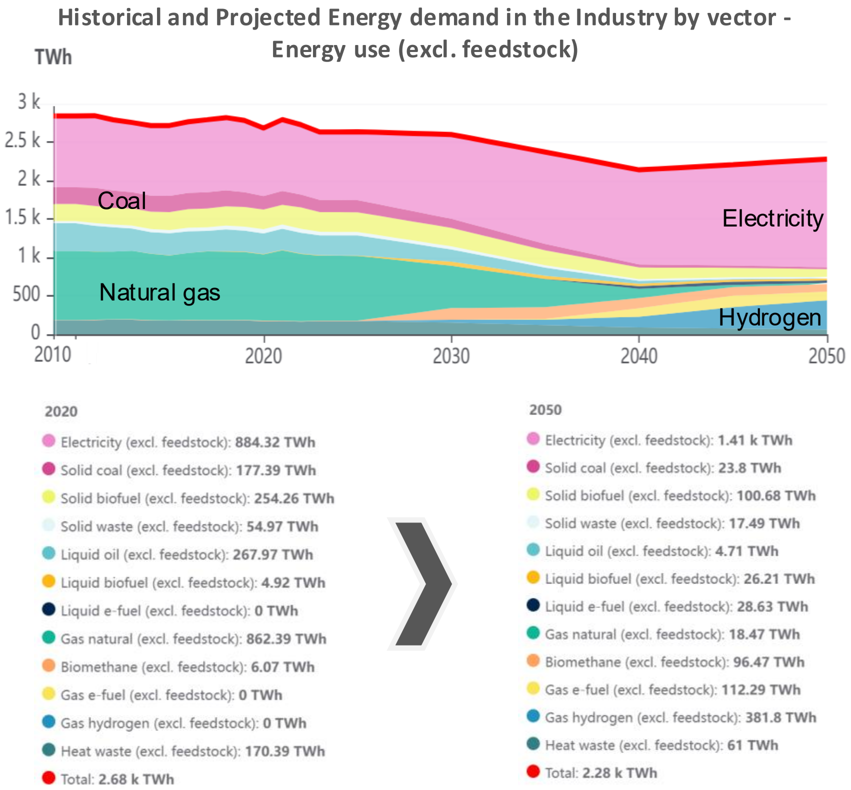
Industrial processes account for ~20% of EU GHG emissions

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



Source: Sintef, European Commission. DG Research and Innovation & Capture Map.

Electrification and hydrogen are key transition vectors



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

Policy and Strategic Drivers

Fit for 55: *Make the EU legally and economically fit to achieve at least –55% net GHG emissions by 2030, on the path to climate neutrality by 2050*

- Tightens carbon pricing and sectoral standards, increasing the cost of fossil heat and fuels
- Shifts investment toward **electrified heat, processes, and efficiency-led solutions**
- Explicitly framed as *fair, cost-effective, and competitive*

- Pushes hard-to-abate sectors to adopt low-carbon solutions
- Positions hydrogen for feedstocks and high-temperature applications where electrification is limited

REPowerEU: *Reduce dependence on imported fossil fuels and accelerate clean energy deployment*

- Frames energy efficiency, fuel switching, and electrification as core levers to cut gas demand

- Concrete objective: 10 Mt renewable hydrogen produced in the EU + 10 Mt imported by 2030

Net-Zero Industry Act (NZIA): *Strengthen EU competitiveness and resilience through domestic clean-tech manufacturing by ↓strategic dependencies and ↑ deployment*

- Scales supply chains for electrification-enabling technologies (e.g. heat pumps, grids, power electronics)
- Simplifies permitting and improves financing conditions for clean-tech projects

- Strengthens the investment and manufacturing environment for hydrogen technologies, notably electrolysers and fuel cells
- Moves hydrogen from pilot phase toward industrial scale

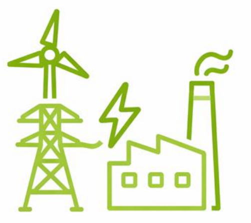
Clean Industrial Deal: *Turn decarbonization into a driver of growth in response to high energy costs and global competition*

- Lowering energy costs and improving efficiency makes electrification the central pathway for many industrial uses

- Retains hydrogen as a strategic solution for hard-to-electrify applications, within a more realistic, targeted deployment logic

Source:

Distinct Roles of Electrification and Hydrogen



Complementarity, not competition!

Electrification – Efficiency-First Pathway

- Direct and highly efficient substitution for industrial heat and mechanical drive
- 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, reweries, paper mills) and rapidly advancing toward 200–250 °C for food, chemical and steel processes
- **Direct electric heating at higher temperatures**, reduces flue-gas losses and enables smarter waste-heat integration, **delivering immediate CO_2 reductions** if using clean electricity

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

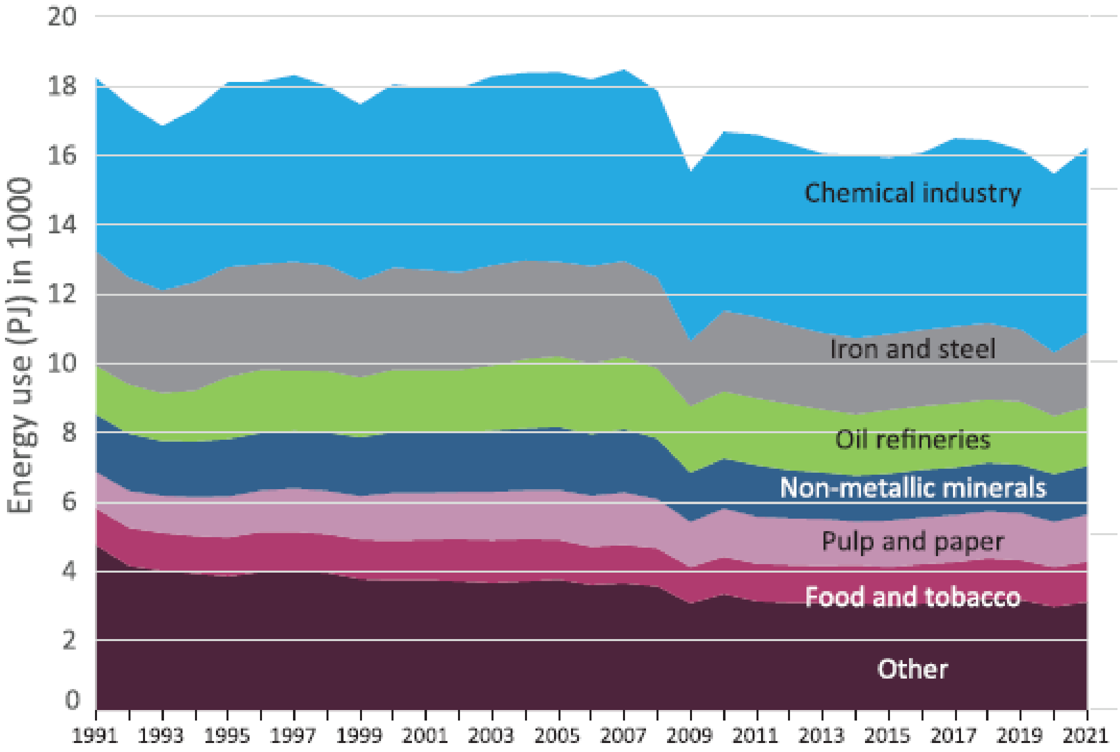
Hydrogen as Energy Carrier – Targeted Use

- Enables very high-temperature processes (>800–1,000 °C):
- Steel, glass, cement (selected processes)
- 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

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

Energy Demand by Industrial Sectors



Source:

Breakdown of final energy consumption in EU industry by energy carrier (2023 data):

Fuel / Energy carrier	Share (% of total final energy in industry)
Electricity	~32.6 %
Natural gas	~31.3 %
Oil & petroleum products	~11.4 %
Renewables & biofuels	~11.2 %
Solid fossil fuels	~6.0 %
Derived heat	~5.3 %
Non-renewable waste	~2.1 %

Industrial Energy and Emissions Challenge

GHG Emissions by Industrial Sectors

Subsector	Representative EU GHG Contribution
Iron & Steel	~25.5 % of industry ETS emissions (~145 Mt CO_2 in 2023)
Cement & Non-metallic Minerals	~124 Mt CO_2 in ETS industry (second-largest)
Chemicals	~155,495 kt CO_2-eq (~5 % of total EU GHG in 2021)
Pulp & Paper	Small single-digit share of total EU industrial emissions (not explicitly disaggregated)
Food / Agro-Food Manufacturing	Low share within industrial manufacturing (not separately reported in EU aggregated data)

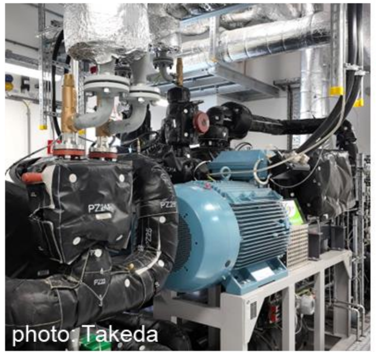
Source:

Electrification: The Efficiency-First Pathway

Use Cases

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)



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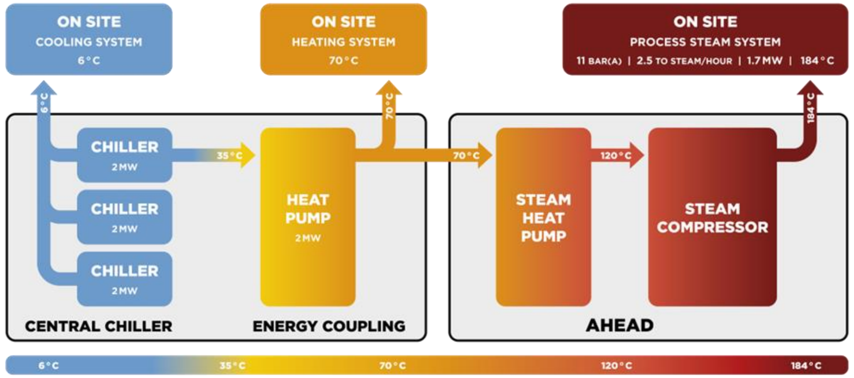

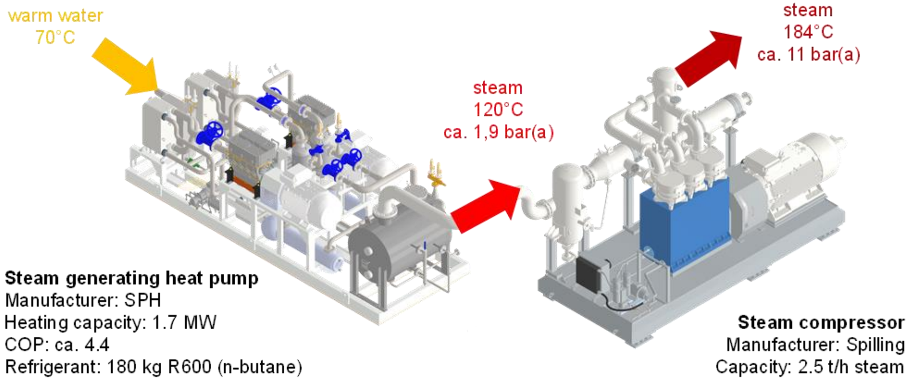

AIT AUSTRIAN INSTITUTE OF TECHNOLOGY | klima+ energie fonds | Takeda | SPH | NEFI NEW ENERGY FOR INDUSTRY

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Source:

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Electrification: The Efficiency-First Pathway

Use Cases

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GREENBRICKS

NEFI NEW ENERGY FOR INDUSTRY

- **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)

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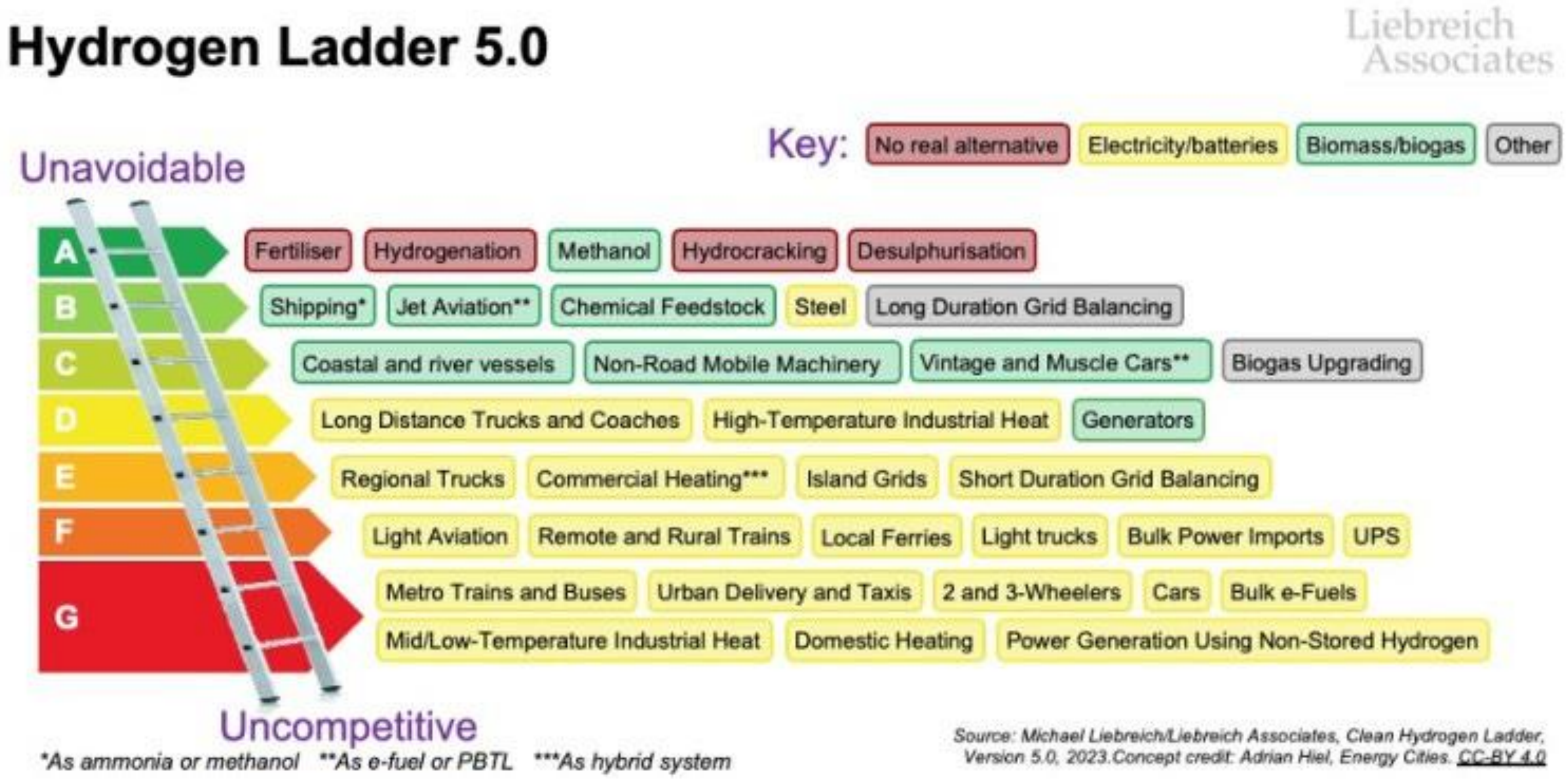
Source:

Hydrogen: Where It Is Truly Essential

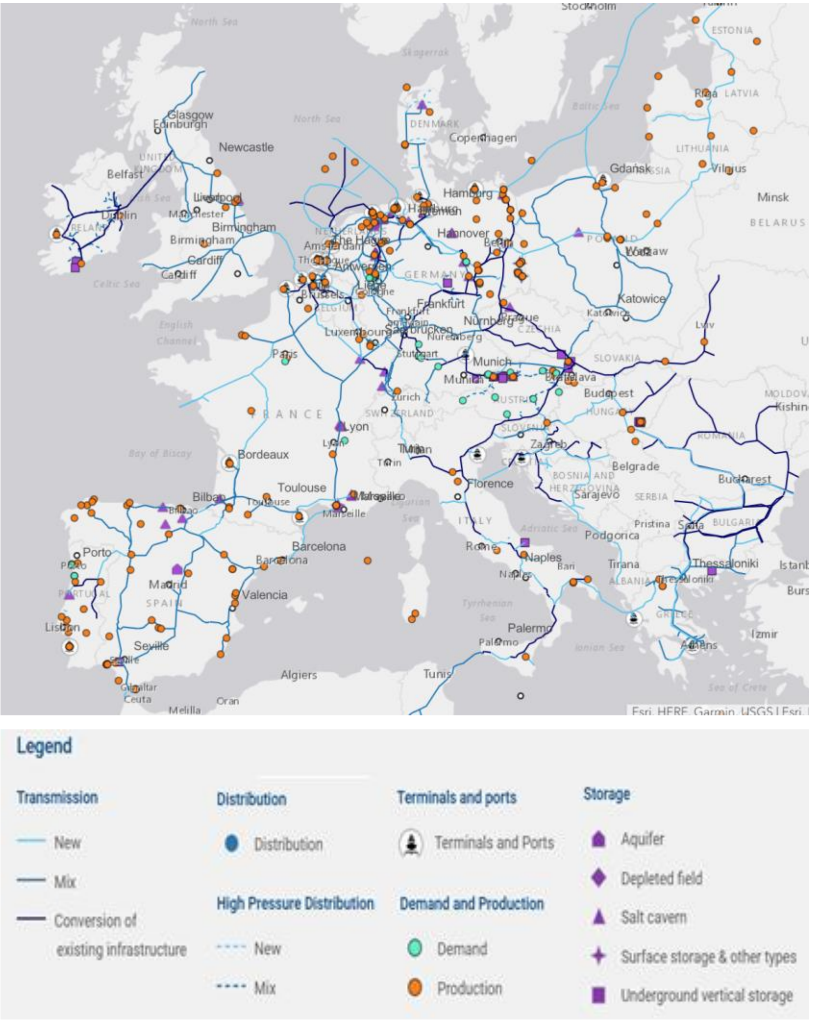
Industry: (1) Feedstock & DRI, (2) long duration grid balancing, (3) high temperature industrial heat



Source:

Infrastructure and Market Constraints

https://www.h2inframap.eu/#introduction



- •Electricity grids: congestion, connection delays, price volatility
- •Hydrogen networks: mostly in planning phase
- •Energy prices in the EU remain structurally high post-Ukraine war
- •Investment risks driven by:
- •Energy price uncertainty
- •Infrastructure availability
- •Changing regulation and markets

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

Source:

Policy Recommendations	Key Actions
Adopt an electrification-first and efficiency-first principle for industry	• Make direct electrification (industrial heat pumps, resistive/inductive heating, electric drives) the default for low- and medium-temperature heat and mechanical drive • Recognise electrification as part of a broader efficiency strategy, including process optimisation, heat integration, waste heat recovery, electrochemical processes, and membrane separations • Clarify that electrification substitutes fossil energy carriers used to generate heat, not "heat itself"
Ensure access to affordable, low-carbon electricity for industry	• Scale long-term price hedging instruments (PPAs, CfDs) for industrial consumers • Address electricity market distortions that prevent renewable penetration from lowering industrial power prices • Treat electricity affordability as a core industrial and decarbonisation policy
Condition hydrogen support on system efficiency and low-carbon electricity	• Tie hydrogen subsidies and contracts to credible access to low-carbon electricity • Avoid hydrogen production that diverts scarce clean electricity from more efficient direct uses • Assess hydrogen projects based on system-level efficiency and emissions impacts
Accelerate grid and system infrastructure as core industrial policy	• Fast-track permitting for grid expansion, reinforcement, and digitalisation • Enable anticipatory investments reflecting future electrification and electrochemical processes • Incentivise flexibility, storage, and demand-side solutions
Create targeted hydrogen demand without assuming hydrogen is the only option	• Prioritise hydrogen for feedstocks (ammonia, methanol, refining), reduction processes (e.g. steel DRI), energy storage, and fuel import options • Explicitly recognise existing and emerging electric high-temperature solutions (EAF steel, Acheson furnaces, electric glass melting) • Avoid broad hydrogen mandates where electrification or process redesign is viable
Enable pragmatic transition pathways in hard-to-abate sectors	• Allow stepwise pathways such as natural-gas-based DRI as an intermediate step toward hydrogen-based DRI • Support hybrid electric–fuel configurations during infrastructure build-out • Avoid locking in long-term fossil dependence
Deploy de-risking instruments tailored to first-of-a-kind and transitional projects	• Use CCfDs, Innovation Fund support, and Hydrogen Bank-style auctions • Prioritise projects with clear decarbonisation trajectories and system-efficiency benefits • Focus support on validated industrial offtakers rather than speculative volumes
Strengthen rules to protect climate integrity and system efficiency	• Enforce additionality, temporal and geographical correlation for green hydrogen • Prevent projects that crowd out grid decarbonisation or increase system emissions • Apply lifecycle-based emissions accounting
Promote regional clustering, selective hydrogen corridors, and energy imports	• Support industrial clusters where renewable electricity, hydrogen, and demand co-locate • Develop hydrogen backbones selectively, based on committed demand • Assess future energy imports (e.g. ammonia) through a system-efficiency and security lens
Treat safety, standards, and skills as enabling policy pillars	• Harmonise EU-wide safety standards and certification for electrified and hydrogen systems • Invest in workforce training, reskilling, and operational capabilities

Source:

R&I Priorities

R&I Priority		
1. High-temperature electrification technologies	Enable electrification of existing and new industrial processes	• Scale resistive, inductive, and microwave heating • Multi-MW systems, brownfield retrofitability, and operational reliability
2. Advanced high-temperature heat pumps	Extend electrification to higher-temperature process heat	• Push delivery temperatures beyond current limits • Improve efficiency at high temperature lift and integration with waste heat
3. Hybrid systems and thermal energy storage	Manage intermittency and grid constraints while maintaining reliability	• Hybrid electric–fuel systems • Cost-effective TES integration to reduce peak demand and grid stress • More flexible operation of processes
4. Competitive and flexible hydrogen production and use	Improve the efficiency, flexibility, and safety of hydrogen systems	• Higher-efficiency, durable electrolysers • Flexible operation under variable renewables and waste-heat integration • Low-NOx burners and multi-fuel high-temperature end-use technologies
5. Industrial feedstock transformation	Decarbonise process-related emissions in hard-to-abate sectors	• Hydrogen-based DRI in steel • Green feedstocks for chemicals and refining • Process redesign to reduce overall energy demand
6. Digitalisation, materials, and system integrity enablers	Enable scale-up, optimisation, and credible climate performance	• Digital twins, AI-assisted operations, and flexible scheduling • Critical materials and components (compressors, power electronics, HTHP materials) • Leak detection, monitoring, and lifecycle accounting (MRV)

Source:

Recommendations – overall

1. Monitor energy use and implement audits

2. Update, share and implement best available practices

3. Create long term decarbonization plans aligned among policy makers, energy network companies and industry

4. Support implementation of new energy-efficient technologies

5. Support R&D for energy-efficient innovations

6. Ensure level playing field for low emission industries