November 2026

Fraunhofer

Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V. | Hydrogen Network

Renewed EU Hydrogen Strategy

For a more competitive and resilient Europe

1 Executive Summary

Europe should move from headline hydrogen ambitions toward an implementation framework based on comparative climate value, credible demand, project maturity, integrated infrastructure planning and industrial capability.

Fraunhofer welcomes the European Commission's initiative to renew the European Hydrogen Strategy. Renewable and low-carbon hydrogen and its derivatives will be important components of a climate-neutral, resilient and competitive European energy and industrial system. Their value is greatest where hydrogen is required as a molecule, where direct electrification is technically constrained or where dispatchable storage and system services create demonstrable benefits. Hydrogen deployment should therefore be treated as a means to achieve decarbonization, competitiveness and resilience—not as an objective in itself [1, 4, 5].

The evidence indicates that European market development remains substantially below earlier trajectories. At the same time, Europe already has significant fossil-based hydrogen demand, concentrated in refining and chemicals. Converting viable incumbent uses can provide near-term emissions reductions, while new applications should be prioritized through application-specific comparison with direct electrification and other credible alternatives. The strategic scale up of renewable energy and associated grid expansion constitutes a prerequisite for an effective development of hydrogen production capacities. [2, 3, 8].

A renewed strategy should combine selective market creation with adaptive infrastructure development and sustained investment in Europe's technological base. Public policy should address the specific causes preventing final investment decisions: production costs, electricity-price exposure, uncertain offtake, limited willingness to pay, counterparty risk, infrastructure timing and regulatory uncertainty. Supply-side premiums alone cannot resolve all of these barriers [2, 3, 11].

Applied research is a strategic implementation capability. Europe needs continuous pathways from materials and components through pilot production, demonstration, testing, qualification and standardization to industrial deployment. These pathways reduce technical uncertainty, create evidence for investment and regulation, and enable companies—especially SMEs—to access capabilities they cannot maintain individually. Public research and innovation support should target technical and industrialization gaps; it should not substitute for market instruments where the dominant barrier is commercial demand or price [4, 9, 14, 15].

Content

1 Executive Summary 1
2 Strategic orientation and problem definition 2
3 Priority demand, applications and credible market creation 3
4 Integrated infrastructure, electricity-system integration and supply portfolio 4
5 Bankability, market framework and investment certainty 5
6 Applied research, industrialization, standards, skills and transfer 5
7 Conclusion 7
8 References 8

Main strategic principles

PRINCIPLE	IMPLICATION FOR THE RENEWED STRATEGY
Value before volume	Prioritize hydrogen uses that demonstrate lifecycle and system value against alternatives such as electrification, efficiency, circularity, sustainable biomass and CCS counterfactuals.
Maturity before announcements	Use harmonized, dated reporting for announced, awarded, FID, construction and operational status.
Integration before isolated assets	Plan hydrogen, electricity, renewables, storage, industrial demand and imports jointly and test infrastructure against low-demand cases.
Risk-specific support	Link each public instrument to a defined investment barrier, causal mechanism, additionality test and exit condition.
Innovation through transfer	Connect applied R&I, demonstration, qualification, standards, industrialization and SME transfer in a continuous European innovation pathway.

2 Strategic orientation and problem definition

Fraunhofer supports the Commission's objectives of strengthening the competitiveness and resilience of the European hydrogen value chain in a renewed strategy that incorporates the implementation experiences since 2020.

The Commission's diagnosis of high costs, weak demand, limited firm offtake, few final investment decisions and infrastructure uncertainty is broadly supported. The causal interpretation nevertheless requires differentiation. Hydrogen costs are strongly dependent on electricity prices, the match between renewable energy generation profiles and capacities and electrolyzer utilization, financing, location and the costs of transport and storage. Fraunhofer CINES analysis shows that delivered hydrogen costs differ materially by customer profile and that transport and storage can be especially significant for low-utilization applications [5]. Generation cost alone is therefore an incomplete indicator. In some markets the binding constraint is production cost; in others it is the absence of creditworthy buyers, uncertainty about infrastructure or competition from conventional and imported products.

A value-oriented strategy should use direct electrification[1] and efficiency as reference cases. This does not diminish hydrogen's strategic role. It concentrates scarce renewable electricity and hydrogen on uses where molecular functionality, process requirements, energy density, storage or system integration provide a comparative advantage [4, 8, 12].

1 *Prioritize hydrogen according to comparative climate and system value.*

The Commission should introduce application-specific assessment that compares hydrogen with direct electrification, energy efficiency, circularity, sustainable biomass, CCS and other credible low-carbon options on a process chain level. The method should report lifecycle emissions, energy efficiency, cost, infrastructure needs, maturity, scalability and European value creation separately. Because methodological boundaries remain contested, the Commission should support pre-normative research and transparent pilot application before using a single assessment method as a binding eligibility threshold.

[1] In addition to electric heating this should also take into account electrochemical material conversion, electric reactors, and electrified separation processes.

2 *Improve transparency on actual market maturity.*

EU strategies, funding dashboards and infrastructure plans should apply harmonized definitions for announced, selected or awarded, final-investment-decision, construction and operational status, together with dated attrition tracking. This would improve policy learning and investor information while avoiding the conflation of project pipelines with committed supply [2, 3].

3 Priority demand, applications and credible market creation

During market formation, low-carbon hydrogen will remain scarce and costly. Priority should therefore be given to applications with high comparative mitigation value, credible industrial demand and/or strategic relevance to industrial policy. Existing fossil-hydrogen uses in ammonia and selected chemical processes offer a strong near-term substitution case. Selected refinery applications can also provide near-term demand, although structural decline in fossil-fuel processing must be reflected to avoid protecting non-viable assets [2, 3, 8].

Hydrogen-based direct reduction can contribute substantially to the decarbonization of primary steel production. Its deployment case remains conditional on electricity and hydrogen prices, infrastructure, carbon-price expectations and markets for low-emission materials. Demand-side instruments for steel should therefore be designed with leakage, affordability and additionality safeguards. Public procurement and product-based standards may complement project support where they create verifiable demand for low-emission output [7, 11].

For aviation and maritime transport, hydrogen-derived fuels can address applications with limited direct-electrification options. The appropriate pathway depends on route, carrier, conversion losses, sustainable carbon availability, safety and infrastructure. Policy should avoid prematurely selecting one fuel across heterogeneous use cases. Broad hydrogen deployment in passenger road transport and building heating should not anchor the European strategy where battery-electric mobility, heat pumps, district heating or efficiency measures offer more direct and efficient decarbonization pathways [8, 12].

Demand creation is indispensable. The limited number of firm long-term offtake agreements shows that subsidizing production does not automatically create buyers. Lead-market instruments should be sector-specific and linked to verifiable climate performance. Their distributional effects, downstream product-price impacts and exposure to carbon leakage require explicit assessment [2, 3, 11].

Underlying these measures, an effective and predictable CO_2 price under a reliable EU ETS framework is a fundamental condition for sustainable hydrogen market creation. A credible long-term carbon-price signal strengthens the business case for substituting fossil-based production and provides investors with greater certainty. Targeted lead-market and support instruments should complement this fundamental incentive where specific barriers remain, rather than substitute for effective carbon pricing.

3 *Build credible demand in selected industrial value chains while promoting grid expansion and renewable energy generation scale up.*

Develop sector-specific lead-market instruments for viable incumbent hydrogen feedstock uses and selected steel pathways. Instrument design should be conditional on lifecycle performance, industrial additionality, affordability, leakage risk and a credible transition pathway. Existing assets should not qualify solely because they currently consume hydrogen. The strategic scale up of renewable energy generation capacities and associated grid expansion is a prerequisite for an effective development of hydrogen production capacities.

4 Integrated infrastructure, electricity-system integration and supply portfolio

A mature hydrogen economy will require transport and storage infrastructure, but future demand, location and timing remain uncertain. Fraunhofer system studies show that coordinated infrastructure can reduce system costs and that pipelines, storage and electrolyzers remain important in low-demand scenarios. They also show wide scenario ranges and regional differences. Systematic modeling can help to guide robust planning decisions. However, model results should not be presented as deterministic forecasts [6, 7].

A staged investment with periodic demand revalidation, regional mismatch analysis and low-demand utilization tests would balance the risks of underbuilding and overbuilding. Excessively strict investment gates could delay industrial transformation; unconditional anticipatory construction could socialize underutilization and stranded-asset risk. Cost-allocation principles should make these trade-offs transparent [6, 7].

Repurposing existing gas infrastructure can reduce time and cost where technical integrity, demand location and network configuration support conversion. It should be assessed asset by asset. Storage development likewise requires distinction between geological potential, technically validated deliverability and commercial commitment. Salt caverns have comparatively mature prospects, whereas other geological options require further site-specific demonstration, integrity assessment and monitoring [6, 15].

Electrolyzers may provide system flexibility, but flexible operation is not automatically beneficial, since lower utilization can increase hydrogen cost, and dynamic operation may affect degradation and lifetime. Project-level evaluation should include grid location, renewable profiles, alternative flexibility resources, storage, utilization and component degradation. Fraunhofer Hydrogen Labs provide an example of research infrastructure able to test dynamic operation and grid-integration performance under industrially relevant conditions [15].

Europe will require a portfolio of domestic production and diversified international supply. Imported molecules should not automatically be assumed to be cheaper or more sustainable. Conversion, shipping, storage, reconversion, certification and infrastructure can materially alter both cost and lifecycle performance. Economic efficiency, energy security, climate performance, strategic autonomy and European value creation are distinct objectives and should be reported separately [3, 6, 13].

4 *Plan hydrogen, electricity, storage and imports jointly.*

Use integrated, staged network and storage planning with low-demand scenarios, utilization thresholds, regional mismatch analysis and periodic revalidation. Planning should include electricity-grid expansion, renewable deployment, industrial demand, storage deliverability and import infrastructure. Cost allocation should address both anticipatory-investment needs and stranded-asset risk.

5 *Compare imports and European production on a delivered-system basis.*

Adopt a transparent methodology covering pipeline hydrogen, ammonia, methanol, e-SAF, liquid hydrogen and hydrogen-intensive intermediates such as DRI/HBI. It should report production, conversion, transport, storage, reconversion where applicable, lifecycle emissions, certification, infrastructure, supplier concentration, resilience and European value creation. Current datasets do not support a single route winner under common assumptions; closing this evidence gap should be an explicit European research task.

5 Bankability, market framework and investment certainty

The limited number of final investment decisions reflects multiple, project-specific risks. High production cost and electricity-price exposure interact with uncertain offtake, willingness-to-pay gaps, counterparty risk, infrastructure timing, permitting, regulation and competition from conventional products or imports. A single instrument cannot efficiently resolve all barriers [2, 3, 11].

Competitive production premiums can reduce a production-cost gap, but they do not guarantee a creditworthy buyer or timely infrastructure. Guarantees or two-sided contracts may address selected risks but can transfer substantial commercial exposure to the public sector. Quotas and product standards can create demand but may affect downstream prices and competitiveness. The appropriate package therefore depends on a transparent causal diagnosis [11].

Regulatory predictability remains essential, including coherent implementation of the Renewable Energy Directive, RFNBO rules and the hydrogen and decarbonized gas framework. At the same time, predictability should not preclude evidence-based adjustment where implementation costs or verification constraints become disproportionate. The Commission's 2025 work on import-auction design illustrates that certification availability and RFNBO verification can become practical barriers across jurisdictions [13].

6 *Address investment barriers according to their underlying cause.*

Require every EU funding or market instrument to identify the investment barrier addressed, the causal mechanism, expected response, fiscal exposure, additionality criteria and exit condition. Supply-side premiums should not be treated as sufficient where the dominant barriers are weak offtake, counterparty risk, infrastructure uncertainty or regulatory implementation.

6 Applied research, industrialization, standards, skills and transfer

Europe's long-term competitiveness depends on its capacity to develop, manufacture, validate and continuously improve hydrogen technologies. Fraunhofer's strategic hydrogen field spans materials, cells and stacks, production technology, infrastructure, safety, applications, systems analysis and lifecycle assessment. Its purpose is to translate scientific knowledge into industrially usable solutions [4, 14].

The renewed strategy should maintain a continuous innovation pathway from applied research through demonstration, testing and qualification to industrial scale-up and market transfer. The value of this pathway is practical: it generates validated performance data, reduces technical uncertainty, supports standards and enables companies—especially SMEs—to access specialized equipment and expertise. Nevertheless, public R&I support should be additional. Mature projects whose main barrier is price or offtake require market instruments rather than an R&I label.

Priority technical gaps include PFAS and critical-material substitution, catalyst and membrane durability, dynamic degradation, manufacturing yield and automation, recycling, lifecycle assessment, hydrogen quality, storage integrity, predictive safety and system integration. Fraunhofer-led initiatives including Referenzfabrik.H2, TransHyDE and the Hydrogen Labs illustrate how shared research platforms can connect technology development with pilot production and industrial validation [4, 6, 14, 15].

Electrolyzer assessment should progressively incorporate verified efficiency under realistic operation, degradation, lifetime, resource use, recyclability and lifecycle emissions. These indicators can improve procurement and support design, but harmonized methods and validated thresholds are not yet

sufficiently mature for a single mandatory European score. Pre-normative research, interlaboratory comparison and open performance data should precede binding thresholds [14, 15].

Independent testing, metrology and qualification are necessary for safe, bankable deployment. Before financing a new European facility network, the Commission should map existing assets, capabilities, throughput, waiting times and utilization. New investment should demonstrate unmet demand, European additionality, open access, interoperability and a sustainable governance and operating model. Current evidence does not yet establish the scale or configuration of an additional EU wide facility network.

7 *Strengthen applied research and industrial transfer.*

Maintain support across the innovation chain—from materials and components through engineering, demonstration, qualification and pilot production to industrialization and transfer. Calls should be designed by dominant bottleneck and technology readiness level, with clear participation routes for industry and SMEs. Commercial demand failures should be addressed through market instruments, not relabeled as research gaps.

8 *Strengthen lifecycle performance, testing and qualification.*

Establish harmonized reporting and test protocols for efficiency, degradation, lifetime, resource use, recyclability and lifecycle emissions. Commission an EU inventory and gap assessment of testing, qualification and metrology capacity; fund additional open-access assets only where unmet demand and European added value are demonstrated.

Skills and implementation capacity

Hydrogen value chains require competencies in research, engineering, construction, operation, safety, metrology, regulation and project management. A Fraunhofer IAO study based on 130 German hydrogen-related job advertisements identifies a broad competence profile and highlights the relevance of technical, organizational and regulatory skills [9]. This evidence is useful for curriculum design but is not sufficient to quantify an EU-wide workforce shortage or determine the scale of a dedicated program.

9 *Base skills policy on quantified needs.*

Undertake an EU-wide competence and workforce-gap assessment differentiated by occupation, qualification level, technology, region and project phase. Use the results to target modular training, reskilling and SME support and link programs to real demonstration, testing and operating environments. Until the evidence base is stronger, avoid unsupported EU-wide shortage estimates.

Natural hydrogen and emerging sources

Natural hydrogen is scientifically relevant, but geological occurrence does not yet establish a recoverable resource, sustainable flow rate or commercial readiness. Further research is required to establish robust European evidence regarding resource size, sustained production, environmental impact, extraction cost and deployment timing. Premature targets could distort expectations and investment.

10 *Maintain an evidence-based approach to natural hydrogen.*

Support stage-gated exploration science, environmental baselines, resource and flow verification, extraction research and monitoring, reporting and verification with open data. Do not establish EU deployment volumes or use commercial-readiness language until recoverability, environmental performance and realistic costs have been independently demonstrated.

7 Conclusion

Fraunhofer main messages:

1. Prioritize hydrogen according to comparative climate and system value.
2. Improve transparency on actual market maturity.
3. Build credible demand in selected industrial value chains while promoting grid expansion and renewable energy generation scale up.
4. Plan hydrogen, electricity, storage and imports jointly.
5. Compare imports and European production on a delivered-system basis.
6. Address investment barriers according to their underlying cause.
7. Strengthen applied research and industrial transfer.
8. Strengthen lifecycle performance, testing and qualification.
9. Base skills policy on quantified needs.
10. Maintain an evidence-based approach to natural hydrogen.

Europe has substantial scientific, technological and industrial capabilities in hydrogen. The central task for the renewed strategy is to translate these capabilities into climate-effective demand, bankable projects, efficient infrastructure and globally competitive value chains. This requires clearer prioritization and more disciplined use of evidence.

Hydrogen should be deployed where it offers comparative climate and system value. Infrastructure should be developed adaptively and tested against realistic demand. Public support should address clearly diagnosed risks. International partnerships should diversify supply while maintaining European capability in technologies, standards, verification and industrial production.

Applied research and effective transfer are integral to this implementation agenda. They connect scientific advances with industrial requirements, validate performance under realistic conditions, support standards and qualification, and reduce barriers to industrial uptake. The renewed strategy should therefore treat research, demonstration, testing, industrialization and market creation as connected—but distinct—functions within one European innovation and deployment system.

With this approach, the European Union can move from announced ambition to measurable implementation while advancing decarbonization, competitiveness, resilience and energy security.

Contact: Katrin Mögele, Fraunhofer EU Office, katrin.moegele@zv.fraunhofer.de

8 References

[1] European Commission (2026). A Renewed Hydrogen Strategy for a More Competitive and Resilient Europe: Call for Evidence. Ref. Ares(2026)10035347, 26 October 2026. Brussels: European Commission. Consultation framing document.

[2] European Union Agency for the Cooperation of Energy Regulators (ACER) (2026). European Hydrogen Markets 2025: Market Monitoring Report. Ljubljana: ACER. Published 13 November 2026. Official source

[3] International Energy Agency (IEA) (2026). Global Hydrogen Review 2026. Paris: IEA.

[4] Fraunhofer-Gesellschaft (2024). Wettbewerbsfaktor: Die Rolle des Wasserstoffs im Energiesystem der Zukunft. Positionspapier zur Bundestagswahl 2025. Munich: Fraunhofer-Gesellschaft. DOI: 10.24406/publica-4141. Official source

[5] Wietschel, M.; Jansen, L.; Pfluger, B.; Frischmuth, F.; Weissenburger, B. (2026). Anwendungsspezifische Wasserstoffbezugskosten in Deutschland 2035. Karlsruhe, Kassel, Cottbus and Berlin: Fraunhofer CINES. Official source

[6] Ausfelder, F.; Ragwitz, M.; Förster, M. Y.; Nolden, C. (eds.) and TransHyDE Project System Analysis (2025). European Hydrogen Infrastructure Planning: Latest Insights from TransHyDE System Analysis. TransHyDE flagship project publication. Official source

[7] Fraunhofer IEG; Fraunhofer ISI; d-fine (2025). Integrated Infrastructure Planning and 2050 Climate Neutrality: Deriving Future-Proof European Energy Infrastructures. Cottbus, Karlsruhe and Frankfurt: Fraunhofer IEG / Fraunhofer ISI / d-fine.

[8] Fraunhofer ISI; Fraunhofer ISE; Fraunhofer IEG (2021). Metastudie Wasserstoff – Auswertung von Energiesystemstudien. Study commissioned by the German National Hydrogen Council. Freiburg and Karlsruhe: Fraunhofer. Official source

[9] Fraunhofer IAO (2025). Wasserstoff als nachhaltiger Energieträger – Qualifikations- und Kompetenzanforderungen einer entstehenden Wasserstoffwirtschaft. Stuttgart: Fraunhofer IAO. DOI: 10.24406/publica-4763. Official source

[10] European Court of Auditors (2024). The EU's Industrial Policy on Renewable Hydrogen: Legal Framework Has Been Mostly Adopted – Time for a Reality Check. Special Report 11/2024. Luxembourg: Publications Office of the European Union. Official source

[11] European Commission (2025). Assistance in the Development of an Auction Design and Necessary Pre-conditions for a European Import Auction for Renewable Hydrogen under the European Hydrogen Bank. Brussels: Directorate-General for Climate Action.

[12] Pfluger, B.; Oberle, S.; Manz, P.; Fritz, M. (2025). Heizen mit Wasserstoff: Aufwand und Kosten für Haushalte anhand aktueller Daten und Prognosen. Cottbus and Karlsruhe: Fraunhofer IEG / Fraunhofer ISI. Official source

[13] European Commission (2023). Commission Delegated Regulation (EU) 2023/1184 supplementing Directive (EU) 2018/2001 by establishing a Union methodology setting out detailed rules for the production of renewable liquid and gaseous transport fuels of non-biological origin; and Commission Delegated Regulation (EU) 2023/1185 establishing a minimum threshold for greenhouse-gas savings of recycled carbon fuels and a methodology for assessing greenhouse-gas savings from RFNBOs and recycled carbon fuels. Official Journal of the European Union.

[14] Fraunhofer-Gesellschaft (2026). Wasserstofftechnologien: Strategic Research Field and Fraunhofer Hydrogen Network. Munich: Fraunhofer-Gesellschaft. Information available by 17 November 2026. Official source

[15] Fraunhofer IWES (2026). Elektrolyseurvalidierung und -qualifizierung: Fraunhofer Hydrogen Labs. Bremerhaven, Leuna and Görlitz: Fraunhofer IWES. Information available by 17 November 2026. Official source