Hydrogen and the Global Energy Transformation

Strategic Insights for Decarbonisation, Energy Security & Industrial Transition

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EXECUTIVE SUMMARY

Why Hydrogen Matters Now

Strategic Context

Hydrogen represents a pivotal enabler for achieving Net Zero targets, enhancing energy security, and maintaining industrial competitiveness in a carbon-constrained global economy.

Key Strategic Takeaways

- Hydrogen offers versatile decarbonisation pathways across transport, industry, and power generation sectors
- Multiple production routes exist with varying carbon intensities, costs, and scalability profiles
- Infrastructure readiness and policy frameworks remain critical enablers for deployment at scale
- Strategic decisions today will shape hydrogen's role in the 2030–2050 energy transition

Source: Strezov, V., Cho, H. H., Sharma, A., & Evans, T. (2025). The Role of Hydrogen in Energy Transformation. Oil, Gas and Energy Law, 23(3), 1–18.

Hydrogen's Role in the Energy Transition

Hydrogen functions as a critical decarbonisation vector capable of addressing emissions across hard-to-abate sectors whilst providing essential energy system flexibility. Its versatility positions it uniquely within the energy transition architecture.

Heavy Industry

Enabling deep decarbonisation in steel, cement, and chemicals production where electrification proves technically or economically challenging

Transport Sector

Providing zero-emission solutions for long-haul freight, aviation, and maritime applications requiring high energy density

Energy Systems

Offering seasonal storage, grid balancing, and dispatchable power generation to complement variable renewable energy sources

Hydrogen Production Pathways

Production methodology fundamentally determines hydrogen's carbon intensity, economic viability, and scalability potential. Understanding pathway characteristics enables strategic technology selection aligned with decarbonisation objectives.

Green Hydrogen

Production: Water electrolysis powered by renewable electricity

Carbon Intensity: Zero direct emissions

Status: Highest cost currently; declining rapidly with renewable energy cost reductions and electrolyser scale-up

Fossil-Based Production

Production: Steam methane reforming or coal gasification, with optional carbon capture and storage (CCS)

Carbon Intensity: High without CCS; significantly reduced with CCS deployment

Status: Lowest current cost; existing infrastructure advantage

Nuclear-Enabled Hydrogen

Production: High-temperature electrolysis or thermochemical cycles using nuclear heat

Carbon Intensity: Near-zero lifecycle emissions

Status: Emerging technology; offers baseload production stability

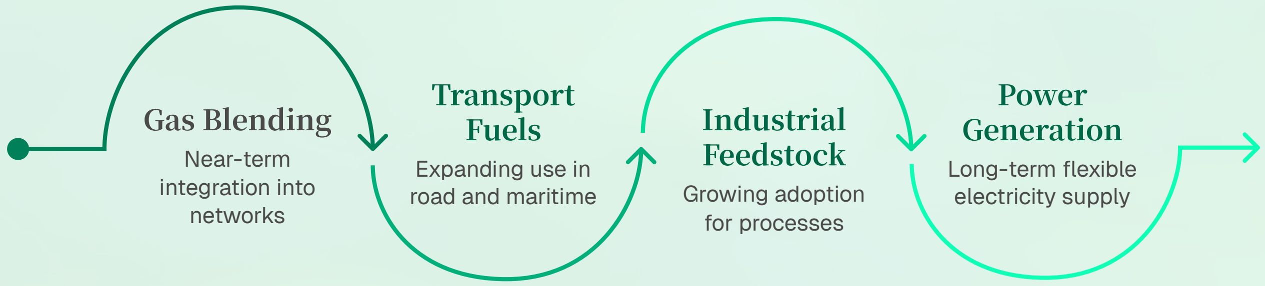
Biomass-Based Routes

Production: Gasification of sustainable biomass feedstocks

Carbon Intensity: Potentially carbon-negative with CCS integration

Status: Limited by sustainable biomass availability; niche applications

Priority Applications: Immediate to Medium Term



Strategic deployment prioritises applications where hydrogen offers distinct technical or economic advantages, enabling progressive infrastructure development and market maturation.

Gas Network Blending

Immediate opportunity using existing infrastructure; regulatory approval advancing in multiple jurisdictions

Transport Fuels

Heavy-duty, long-haul applications demonstrating commercial viability; refuelling infrastructure expanding

Green Steelmaking

Direct reduced iron processes eliminating coal dependency; pilot projects scaling to commercial production

Power Generation

Fuel cells and hydrogen-capable turbines providing flexible, dispatchable zero-carbon electricity

Infrastructure and System Readiness

Infrastructure development constitutes a critical enabler and potential constraint for hydrogen deployment at scale. Strategic infrastructure planning must address storage, transmission, and distribution requirements whilst leveraging existing assets where feasible.

1

Storage Solutions

Underground salt caverns, depleted gas fields, and above-ground compressed/liquid storage providing seasonal flexibility and supply security

2

Transmission Networks

Dedicated hydrogen pipelines for high-volume corridors; repurposing natural gas infrastructure where metallurgical compatibility permits

3

Distribution Systems

Local pipeline networks, tube trailer delivery, and refuelling stations supporting end-user access across industrial and transport applications

4

Technology Readiness

Most infrastructure technologies proven; focus shifting to cost reduction, standardisation, and regulatory frameworks for scaled deployment

Policy and Regulatory Landscape

Global Hydrogen Strategies

Major economies have established national hydrogen strategies targeting production capacity, infrastructure investment, and demand creation. The European Union, Japan, South Korea, and Australia lead policy development, whilst the United States and China are rapidly scaling ambitions.

Policy mechanisms include production subsidies, carbon pricing, mandates for industrial hydrogen use, and support for infrastructure development. Divergent approaches reflect varying energy security priorities, industrial structures, and decarbonisation timelines.

Standards and Certification

International standards development addresses safety protocols, equipment specifications, and carbon intensity certification. Guarantees of origin schemes emerging to differentiate low-carbon hydrogen and enable premium pricing for green production.

Market Mechanisms

Carbon pricing, contracts for difference, and green procurement mandates driving hydrogen competitiveness

Geopolitical Dimensions

Export opportunities for renewable-rich nations; energy independence considerations reshaping trade relationships

Regulatory Harmonisation

Cross-border trade requiring aligned safety standards, certification schemes, and grid code compatibility

Risks, Constraints and Open Questions

Whilst hydrogen presents significant decarbonisation potential, material risks and uncertainties require careful consideration in strategic planning and investment decision-making.

Cost and Scalability Challenges

Green hydrogen production costs remain 2–3 times higher than fossil-based alternatives in most markets. Achieving cost parity requires continued reductions in renewable electricity costs, electrolyser capital costs, and utilisation improvements. Scale-up timelines may constrain 2030 deployment targets.

Infrastructure Lock-In Risks

Substantial capital investments in hydrogen infrastructure create path dependencies. Premature commitment to specific technologies or routes may strand assets if alternative solutions prove more cost-effective. Coordination between production, infrastructure, and demand development presents planning complexity.

Carbon Intensity Uncertainties

Lifecycle emissions from fossil-based hydrogen with CCS depend critically on capture rates, methane leakage, and electricity grid carbon intensity. Certification schemes and monitoring protocols remain under development. Greenwashing risks exist without robust verification frameworks.

Policy and Market Volatility

Investment decisions face regulatory uncertainty regarding subsidy continuation, carbon pricing trajectories, and mandate stringency. International policy divergence may fragment markets and complicate cross-border trade. Technology competition from alternative decarbonisation pathways introduces market risk.

Strategic Implications for Industry and ESG

Industry Leadership Opportunities

First-mover advantages exist for organisations establishing hydrogen value chains, securing low-cost renewable energy access, and developing proprietary technologies. Strategic partnerships across production, infrastructure, and end-use sectors accelerate capability development.

ESG and Net Zero Integration

Hydrogen strategies must align with science-based decarbonisation targets and ESG commitments. Transparency regarding production pathways, carbon intensity, and lifecycle emissions proves essential for credible Net Zero roadmaps. Stakeholder expectations increasingly differentiate green hydrogen from fossil-based alternatives.

Near-Term Strategic Decisions

- Assess hydrogen's role within corporate decarbonisation strategies
- Evaluate production pathway options aligned with cost, carbon, and risk tolerance
- Engage policy development to shape supportive regulatory frameworks
- Pilot deployment in priority applications to build operational experience

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Research Source and Contact

This briefing synthesises peer-reviewed research to support strategic decision-making in hydrogen systems, energy transition pathways, and Net Zero strategies.

Primary Research Source

Strezov, V., Cho, H. H., Sharma, A., & Evans, T. (2025). The Role of Hydrogen in Energy Transformation. *Oil, Gas and Energy Law*, 23(3), 1–18.

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Strategic advisory for energy transition, decarbonisation pathways, and ESG integration

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