

Trillion Dollar Hydrogen Infrastructure for Steel



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The Trillion-Dollar Pipeline: Mapping the Hydrogen Infrastructure Investment Needed for Steel Decarbonisation

Executive Summary

The numbers are staggering. To decarbonise global steel production through hydrogen-based direct reduction, the world needs to build hydrogen infrastructure worth more than \$1 trillion over the next two decades¹. To put this in perspective, this investment dwarfs the cost of building the entire U.S. interstate highway system (adjusted for inflation) and rivals the global investment in internet infrastructure since the 1990s.

Yet despite the scale, this infrastructure buildout represents more than just an environmental requirement — it's becoming a competitive necessity. As carbon pricing mechanisms like the EU's Carbon Border Adjustment Mechanism (CBAM) reshape global trade flows, and governments pledge billions in green steel subsidies, the steel companies that secure reliable, cost-effective hydrogen access first will gain major advantages in the emerging low-carbon economy.

The question isn't whether this infrastructure will be built, but where, when, and by whom. The answers will fundamentally reshape the global steel industry's competitive landscape for decades to come.

The Infrastructure Stack: More Complex Than It Appears

Building a hydrogen economy for steel isn't just about producing green hydrogen — it requires building a completely new industrial system. The infrastructure stack spans four critical layers, each with distinct technical challenges and capital requirements.

The Production Layer

The Production Layer represents the most visible component but only about 40% of total infrastructure costs. Converting enough renewable electricity into green hydrogen for steel production requires approximately 300 GW of dedicated electrolyser capacity globally — roughly equivalent to the el



current global offshore wind capacity. Current electrolyzer manufacturing capacity sits at just 8 GW annually, creating a production bottleneck that won't resolve until the late 2020s even with aggressive scaling.

Storage Infrastructure

Storage Infrastructure poses perhaps the greatest technical challenge. Hydrogen's low energy density means steel plants need massive storage capacity to ensure production continuity. A typical integrated steel plant converting to hydrogen would require storage equivalent to 10-15 days of production — potentially hundreds of thousands of cubic meters. Underground salt cavern storage offers the most economic solution, but suitable geology exists in limited locations, forcing many regions toward more expensive above-ground options.

Transport Networks

Transport Networks create the most complex coordination challenges. While existing natural gas pipelines can be retrofitted for hydrogen in some cases, the gas requires dedicated infrastructure for optimal efficiency and safety. The European Hydrogen Backbone initiative envisions 40,000 kilometers of hydrogen pipelines by 2040, with an estimated cost of €80-143 billion. Similar networks are needed across every major steel-producing region.

Plant-Level Integration

Plant-Level Integration often gets overlooked but represents significant hidden costs. Converting a blast furnace facility to hydrogen-based direct reduction isn't just about swapping out equipment — it requires completely redesigning plant layouts, safety systems, and operational procedures. Early estimates suggest plant-level hydrogen integration costs range from \$200-400 million per million tons of annual capacity.

Regional Investment Patterns: A Tale of Three Strategies

The trillion-dollar infrastructure challenge is playing out differently across major steel-producing regions, each reflecting distinct resource endowments, policy frameworks, and competitive dynamics.

Europe: The Integrated Approach

Europe is pursuing the most complete strategy, leveraging its renewable energy advantages and policy coordination. The European Hydrogen Backbone, connecting offshore wind farms in the North Sea to industrial clusters in Germany, Belgium, and the Netherlands, represents a €100+ billion infrastructure bet. The approach integrates hydrogen production, transport, and consumption within unified planning systems.

German steel companies like Thyssenkrupp and Salzgitter are co-investing in dedicated hydrogen infrastructure alongside energy companies and government agencies. Thyssenkrupp's planned billion hydrogen-based direct reduction plant in Duisburg includes €800 million in dedicated infrastructure



— storage, pipeline connections, and grid integration. This model spreads infrastructure costs across multiple stakeholders while ensuring long-term supply security.

Asia-Pacific: The Export-Import Strategy

Asia-Pacific regions are developing infrastructure around international hydrogen trade, reflecting the mismatch between renewable energy resources and steel production centers. Japan, with limited domestic renewable potential, is investing heavily in import infrastructure and international supply chains.

The Japan-Australia hydrogen corridor exemplifies this approach. Australia is developing large-scale hydrogen production facilities in Western Australia and Queensland, while Japan builds import terminals and distribution networks. The total infrastructure investment across both countries exceeds \$50 billion, creating the template for global hydrogen trade.

North America: The Cluster Strategy

North America is organizing hydrogen infrastructure around industrial clusters, leveraging existing chemical and refining infrastructure. The Gulf Coast, with its extensive natural gas pipeline networks and chemical industry expertise, is becoming the epicenter for hydrogen infrastructure development.

The Department of Energy's \$7 billion hydrogen hub program supports infrastructure development in seven regional clusters. The Gulf Coast hub alone represents \$1.2 billion in federal investment, leveraging additional private capital for comprehensive infrastructure development.

Financing Reality: Who Pays for the Trillion-Dollar Infrastructure?

The scale of required investment far exceeds what steel companies can finance independently. Even the largest integrated producers would struggle to fund comprehensive hydrogen infrastructure alongside production facility conversions. This reality is driving new financing approaches that spread costs and risks across multiple stakeholders.

Public-Private Risk Sharing

Governments are providing significant public funding to encourage private investment, but the models vary considerably. European approaches emphasise grant funding and loan guarantees, reducing private sector risks during early deployment phases. The EU's Innovation Fund provides up to €10 billion in grants for low-carbon industrial projects, with hydrogen infrastructure representing a major focus area.

Industry Consortium Models

Steel companies are increasingly joining industry consortiums to share infrastructure costs and risks. The H2 Green Steel project in northern Sweden involves multiple industrial partners sharing hydrogen infrastructure costs. Similarly, the Hamburg Green Hydrogen Hub includes steel, chemical, and other companies co-investing in shared infrastructure.



The UK's Humber Cluster shows complex cost-sharing systems, with £21.7 billion in government commitments distributed across steel, chemicals, refining, and power generation industries. The model includes 18 major companies sharing both infrastructure development costs and operational expenses, with cost allocation based on capacity utilisation. This approach reduces individual company infrastructure costs by 50-70% compared to standalone development².

These consortium approaches spread costs across multiple industries while ensuring adequate scale for economic operation. The strongest candidates for infrastructure cost-sharing with steel include chemical and petrochemical industries, oil refining, fertiliser manufacturing, and aviation fuel production³.

Timeline Mismatches and Financial Stress

A critical challenge involves timing mismatches between infrastructure investment needs and payback periods. Hydrogen infrastructure requires upfront investment years before steel companies need hydrogen supply, creating cash flow challenges for all stakeholders.

Pipeline and storage infrastructure typically requires 20-30 year payback periods, while steel companies face competitive pressures requiring more immediate returns. This mismatch is driving new financing approaches, including infrastructure investment funds and long-term offtake agreements that provide revenue certainty for infrastructure investors.

The Sequencing Dilemma: Chicken, Egg, and Billion-Dollar Bets

Perhaps the most complex challenge facing hydrogen infrastructure development is sequencing. Steel companies won't commit to hydrogen-based production without reliable supply guarantees, while infrastructure developers won't invest without firm demand commitments. This chicken-and-egg problem is forcing new approaches to coordinate investment timing.

Cluster Development and First-Mover Advantages

The most successful hydrogen infrastructure projects are emerging around industrial clusters where multiple companies can share infrastructure costs and provide diversified demand. The Port of Rotterdam's hydrogen infrastructure development serves petrochemical companies, refineries, and steel producers, spreading costs across multiple industries while providing greater revenue certainty.

Phase-Gate Approaches

Many infrastructure projects are adopting phase-gate development approaches that match infrastructure capacity expansion with demand growth. This reduces initial capital requirements while providing expansion options as markets develop.

The European Hydrogen Backbone shows this approach, with initial development focused on connecting major industrial clusters, followed by expansion to connect additional regions as demand grows. This approach reduces upfront investment risks while maintaining expansion flexibility.



Strategic Implications: The New Geography of Global Steel

The trillion-dollar hydrogen infrastructure buildout isn't just about decarbonisation — it's fundamentally reshaping competitive dynamics in global steel. Regions with early, complete hydrogen infrastructure development are gaining competitive advantages that could persist for decades.

New Partnerships Across Traditional Industry Boundaries

Successful hydrogen infrastructure development requires partnerships across traditionally separate industries. Steel companies are partnering with renewable energy developers, pipeline companies, and storage operators in ways that would have been unimaginable a decade ago.

These partnerships are creating new industry networks that blur traditional boundaries. SSAB's partnership with Vattenfall and LKAB shows this trend, integrating steel production, renewable energy, and mining operations within a unified hydrogen system.

Geopolitical Implications of Infrastructure Dependencies

Hydrogen infrastructure development is creating new geopolitical dependencies that mirror but don't replicate traditional energy relationships. Countries with abundant renewable energy resources are becoming potential hydrogen exporters, while traditional energy importers may gain advantages in hydrogen infrastructure development.

The Middle East provides an interesting case study. Countries like Saudi Arabia and the UAE are investing heavily in hydrogen production infrastructure for export markets, potentially extending their roles as energy suppliers into the low-carbon economy. However, their success depends on developing importing regions' willingness to maintain energy import dependencies rather than pursuing domestic production strategies.

Conclusion: Infrastructure as Competitive Strategy

The trillion-dollar hydrogen infrastructure challenge represents more than an engineering problem — it's becoming the key competitive area for the global steel industry's future. Companies and regions that successfully navigate the complex coordination challenges of infrastructure development will gain major advantages in the emerging low-carbon economy.

Success requires thinking beyond traditional industry boundaries and investment horizons. Steel companies must increasingly think like utilities, making long-term infrastructure investments that enable competitive operations decades into the future. Governments must coordinate across multiple industries and policy domains to create supportive policies for private investment.

Most critically, the window for shaping hydrogen infrastructure development is narrowing rapidly. The infrastructure investments made over the next decade will largely determine the global steel industry's competitive landscape through mid-century. For steel industry leaders, the question isn't whether



engage with hydrogen infrastructure development, but how quickly and strategically they can position themselves within emerging hydrogen networks.

The trillion-dollar pipeline isn't just about moving hydrogen—it's about moving the global steel industry toward a fundamentally different competitive future. Those who understand this transformation and act decisively will be the steel leaders of tomorrow's low-carbon economy.

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11th August, 2025

Sources and Notes:

¹ Based on Stegra's (formerly H2 Green Steel) project costs of €6.5 billion for 5 million tonnes of annual hydrogen steel capacity (€1.3 billion per million tonnes), global steel production projections indicate that 660 million tonnes of green hydrogen-based steel capacity will be needed by 2050 to achieve 35% of current global production. At Stegra's cost benchmark: 660 Mt × €1.3 billion/Mt = €858 billion (~\$944 billion). When including additional infrastructure costs beyond plant-level investments (pipeline networks, storage facilities, and grid integration), total hydrogen infrastructure investment requirements exceed \$1 trillion.

² Multi-industry collaboration reduces hydrogen infrastructure costs by 50-90% compared to standalone development. The Humber Cluster's £21.7 billion cost-sharing model demonstrates distributed infrastructure costs across multiple industries. Without cost-sharing, individual steel companies would face infrastructure costs of approximately \$1.5-2.0 trillion globally for hydrogen steel transition. With collaborative development through industrial clusters, total infrastructure costs fall to \$600-900 billion, representing savings of \$600 billion to \$1.1 trillion through shared pipelines, storage facilities, and electrolyser plants.

³ The strongest candidates for hydrogen infrastructure cost-sharing with steel production are: (1) **Chemical and petrochemical industries** - consuming 54 million tonnes of global hydrogen demand with compatible high-purity requirements and 24/7 operations; (2) **Oil refining** - consuming 40 million tonnes globally with established merchant hydrogen networks and 85% external sourcing patterns; (3) **Fertilizer manufacturing** - requiring 178 kg hydrogen per tonne of ammonia across 235 million tonnes annual production, offering substantial volume synergies; (4) **Aviation fuel production** - emerging high-growth sector requiring 3-4 kg hydrogen per kg synthetic fuel with government mandate certainty. These industries offer immediate demand, compatible infrastructure requirements, and proven cost-sharing track records.

⁴ In Steelonthenet.com's view, the most promising locations for future hydrogen steel hubs will combine cost-sharing industries with high-quality iron ore access: **Western Australia (Pilbara-Perth corridor)** leads with world's highest-grade iron ore (65-67% Fe), exceptional renewable resources, and expanding chemical industries; **Northern Sweden (Kiruna-Lulea)** offers premium ore (68%+ Fe) with Stegra's €6.5B project proving viability alongside abundant hydroelectric power; **Eastern Canada (Quebec-Labrador-Newfoundland)** provides high-grade ore (66%+ Fe), the world's cheapest renewable energy, and proximity to North American markets. These regions' combination of ore quality, renewable abundance, and industrial clustering potential positions them to dominate future hydrogen-based steel production over traditional industrial centers lacking direct ore access.



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How to Cite This Article

Kotas, A.M. (2025) 'Trillion Dollar Hydrogen Infrastructure for Steel', *Steelonthenet*. Available at: <https://www.steelonthenet.com/insights/hydrogen-steel-investment-costs.html> (Accessed: 9 February 2026).

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