INTERNATIONAL

What role can hydrogen play in the industrial processes

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Industrial applications are the most widespread and significant of hydrogen uses in operation today, with about 60% being used in ammonia production, 30% in methanol production, and 10% for direct reduced iron in the iron and steel subsector. 1 Almost all hydrogen used in these industrial applications is derived from fossil fuels, contributing to around 680 million tonnes of CO_2 emissions in 2023—an increase of 0.6% since 2022. 2

The industrial sector remains one of the hardest to decarbonise and is a driving factor in the growing demand for hydrogen. The 2023 edition of the IEA's Net Zero Emissions by 2050 Scenario projects that demand will reach 70 million tonnes by 2030, up from 53 million tonnes in 2022. 3 Since the previous Hydrogen Expert Guide published in 2021 (the "**2021 Expert Guide**"), there has been a notable uptick in low-emission hydrogen production in industrial plants, with approximately 285 kilotonnes produced in 2022, up from 240 kilotonnes in 2021. 4

However, challenges such as high production costs, uncertain future demand, lack of infrastructure, and unclear regulations remain significant barriers to adoption. 5 To overcome these obstacles, robust legal and regulatory frameworks capable of supporting the growth of industrial low-carbon hydrogen use are needed. Given the wide range of applications and uses for hydrogen in the industrial sector, this chapter focuses primarily on hydrogen use as a feedstock in industrial heat generation and draws on international examples to highlight the key legal considerations for investors, developers and financiers entering this sector.

Hydrogen Technology in industrial processes – High-intensity heat generation

Industrial heat accounts for two-thirds of industrial energy demand and nearly one-fifth of global energy consumption 6 . High-intensity heat generation directly and indirectly drives numerous processes such as fluid heating, distillation, drying and facilitating chemical reactions. 7 Currently, the primary energy sources for high-temperature industrial heating are fossil fuels —approximately 30%

from coal, 35% from natural gas, and 15% from oil— contributing to about 10% of global greenhouse gas emissions. 8

The use of low- and zero-carbon fuels, such as hydrogen, could significantly reduce emissions. 9 In an ambitious high adoption scenario, it has been estimated that hydrogen could provide approximately half of the energy required to power the UK's industrial, heating and transport sectors by 2050. 10

The production of hydrogen-based fuels has grown significantly. In 2022, global low-emission hydrogen production reached 0.3 million tonnes, primarily driven by ammonia production. Additionally, with over 20 million tonnes of hydrogen equivalent expected to be operational by 2030, hydrogen is increasingly being integrated as a feedstock across a broader range of industries, reflecting its expanding role in decarbonising industrial heat. 11

Opportunities and barriers for hydrogen use in industrial processes

Low-emission hydrogen production is currently dominated by hydrogen 12 produced from natural gas with the associated carbon dioxide captured, transported and stored. Electrolytic hydrogen, produced from renewable electricity such as wind and solar through localised electrolysis, is gaining prominence, having reached almost 520 GW globally in 2023 13 . However, low-emission hydrogen still accounted for only 0.7% of global production in 2022 14 . To increase adoption, some countries' approach has been to focus on industrial clusters to stimulate large-scale demand and attract investment.

Replacing fossil fuel feedstocks with hydrogen is complex due to the diversity of heat-generation technologies across industrial sectors. For instance, in the steel industry, switching to hydrogen-based production presents significant challenges. The high temperatures required for steelmaking, along with hydrogen's different combustion properties compared to those for traditional carbon-based fuels, necessitate modifications to existing infrastructure and processes. For example, the blast furnace-basic oxygen furnace route would need to transition to a direct reduced iron process using hydrogen, which poses technical and economic hurdles. 15

While some hydrogen infrastructure exists, significant investments are still required to support large-scale hydrogen production and transport. Initiatives such as the European Hydrogen Backbone, which aims to develop a 28,000 km hydrogen pipeline network across Europe by 2030, represent significant progress toward reducing the cost of transporting hydrogen and making it a more cost-effective option for industries. 16

A key tool for policymakers is the creation of new regulatory frameworks that facilitate the development and uptake of low-carbon hydrogen technologies 17 . For example, Romania has mandated that industrial hydrogen users meet 50% of their demand with low-emission hydrogen by 2030, demonstrating how national policies can drive the transition to cleaner hydrogen technologies. 18

Ultimately, significant policy support is required if there is to be a significant uptake in hydrogen technology across heat-intensive industrial sectors. Although industrial heat demand is projected to grow by 6% from 2022 to 2027, and modern renewable heat consumption is expected to increase by almost one-third during the same period, these developments are insufficient to fully offset fossil fuel-based heat consumption. Without additional policy intervention, it remains difficult to foresee a significant increase in low-carbon hydrogen adoption. 19

As the hydrogen economy becomes more global, it is anticipated that locally produced hydrogen will increasingly be complemented by cross-border shipments from regions with abundant renewable energy resources and CO_2 storage capabilities. In line with the Net Zero Emissions by 2050 Scenario, more than 20% of merchant demand for hydrogen and hydrogen-based fuels is projected to be met through international trade by 2030. 20 While the economics of such projects remain uncertain, if trans-border hydrogen can be competitively priced against local sources, it could open up new opportunities for industrial users.

The contractual frameworks for these projects are still evolving. In some cases, their structure resembles that of LNG or large-scale cross-border gas transportation and petrochemical projects, where the economics are already established. For others, the contracts may need to follow offtake structures more commonly seen in renewable energy projects, such as power purchase agreements. Alternatively, a hybrid approach may emerge as the market continues to mature.

The challenges with trans-border shipment of hydrogen are primarily technical. To transport hydrogen in liquid form, it must be cooled to minus 253 degrees Celsius, just 20 degrees above absolute zero (the lowest level of the thermodynamic scale), and 100 degrees cooler than LNG. Additionally, the volatility of liquid hydrogen presents complications. However, liquid hydrogen carriers and stabilising catalysts are being developed and tested and expected to be deployed in full-scale projects in the near future. In the meantime, green ammonia, composed of nitrogen and hydrogen, offers a less technically challenging and commercially viable alternative for hydrogen transport.

As of now, export-oriented hydrogen projects are growing, with announced plans suggesting up to 16 Mt of hydrogen equivalent (Mt H2-eq) could be exported globally by 2030, and this figure could increase to 25 Mt H2-eq by 2040 21 . Despite this, progress in pre-existing projects has been slow.

Towards an Effective Framework for Hydrogen in the Industrial Sector

Developers, investors and advisers in the energy sector will recognise that navigating the regulatory regime for energy projects is complex. Numerous regulatory bodies and key stakeholders, including offshore seabed owners, marine management authorities, oil and gas authorities, government departments, shipping authorities, environmental bodies and health and safety executives, oversee low-carbon hydrogen projects, requiring careful coordination among them.

Integrating hydrogen technologies into existing energy systems for use as an industrial feedstock requires a coordinated effort among stakeholders. 22 This includes aligning different countries' domestic regulatory frameworks to support critical infrastructure, particularly for hydrogen transportation and storage.

Some jurisdictions covered by this guide, notably Japan, South Korea and some EU jurisdictions, have already taken steps in this regard. As another example, in the UK, the North Sea Transition Authority had acknowledged the need for regulatory clarification for hydrogen technologies and the rationalisation of stakeholder roles. 23 Since then, key developments have occurred, including the creation of the Hydrogen Regulators Forum in 2021, which has facilitated knowledge-sharing and coordination among regulators, focusing on challenges in planning, environmental, and safety regulations. Notably, the forum has contributed to environmental regulation guidance for CCUS-enabled hydrogen production and revisions to the Energy National Policy Statements to prioritise hydrogen projects in the planning process 24 . However, these initiatives are still in the early stages, as highlighted by the Hydrogen Planning Barriers research project that was completed in December 2023, which identified resource challenges for local authorities and the absence of specific policy guidance as barriers delaying hydrogen projects and increasing costs. Addressing these hurdles will be essential for accelerating hydrogen adoption and ensuring that the UK's hydrogen economy grows efficiently 25 .

Similarly, the Netherlands expressed its intent to regulate hydrogen networks in a similar way to existing gas and electricity networks. 26 The Dutch authorities have acknowledged the gaps in current regulations for the storage of hydrogen. While preferring to have European or international safety guidelines and standards developed, they have begun establishing general principles relating to the safety risks of hydrogen storage with the ultimate aim of developing a bespoke framework specific to hydrogen. 27

Funding the Hydrogen Industrial Market

In a number of jurisdictions covered by this guide, the availability of public and private financing to develop hydrogen technologies for industrial applications is nascent. However, in comparison to the use of hydrogen in transportation, there are fewer examples of funding mechanisms which are specific to the industrial use of hydrogen.

Nevertheless, there are some examples of financing mechanisms, often combining public and private funding, which are being harnessed to develop hydrogen technologies for industrial feedstocks:

- **Germany**: Germany has a well-established precedent of public funding for hydrogen technologies. Specifically, the German Federal Ministry of Education and Research provided over €60 million in funding for the first phase of the "Carbon2Chem" project. This initiative focuses on how industrial gases from steel production can be repurposed into valuable products like fuels, plastics, or fertilisers. An additional €84 million was later allocated for the second phase, which aims to further validate and scale up these processes, with industrialisation expected by 2025 28 . It is expected to make 20 million tonnes of the German steel industry's annual CO_2 emissions economically exploitable in the future. This represents 10% of Germany's annual CO_2 emissions produced by industry and manufacturing. 29
- **UK**: The UK's Net Zero Hydrogen Fund ("**NZHF**") was initially announced in 2021 as part of the then Prime Minister's Ten Point Plan for a Green Industrial Revolution. Under the NZHF, the government planned to allocate £240 million. 30 This fund, to be delivered between 2022 and 2025, was designed to support the upfront costs of developing and constructing low-carbon hydrogen projects. As of 2024, the UK government has awarded £37.9 million 31 in grants to 15 low-carbon hydrogen projects in the first round and a further £21 million in the second round, continuing its commitment to reaching 5GW of low-carbon hydrogen production by 2030. Further to advancing the hydrogen economy in the UK has been the introduction of the Hydrogen Production Business Model under the first electrolytic hydrogen allocation round ("**HAR1**") in July 2022 and the second round ("**HAR2**") which was launched in December 2023. This model utilises a Contracts for Difference framework, referred to as Low Carbon Hydrogen Agreements, which aims to encourage the development of low-carbon hydrogen production by providing both revenue support and capital expenditure ("**CAPEX**") funding. The Hydrogen Production Business Models seek to stimulate the UK's low-carbon hydrogen economy, with a target of 1GW of electrolytic hydrogen production capacity by 2025, and scaling up to 10GW by 2030. Over £2 billion in revenue support and £90 million in CAPEX funding have been made available for projects through this initiative 32 .

Hydrogen industrial clusters

- In an effort to coordinate how clean hydrogen may become a viable solution for decarbonising European economies, in 2020, the European Commission (the "**Commission**") launched a

Hydrogen Strategy for Europe. This strategy provides a comprehensive framework for the European Clean Hydrogen Alliance to develop an investment agenda and project pipeline. Between 2025 and 2030, the strategy anticipates that hydrogen will become deeply integrated into Europe's energy systems. During this period, it is anticipated that demand-side policies will be required to ensure that uptake of hydrogen technologies is realised in industrial settings. A core component of this vision is the establishment of hydrogen industrial clusters, where decentralised renewable energy production would coexist with energy-intensive industries.
- As hydrogen becomes more widespread, the Commission anticipates a growing need for Union-wide transmission infrastructure to transport hydrogen from renewable energy production sites to industrial hubs. To scale up the deployment of hydrogen technologies, EU support and stimulus packages will be required, with the aim of having a competitive hydrogen market operational in the Union by 2030. This will allow hydrogen to penetrate all sectors of the economy, including industries where decarbonisation is currently more costly, as 2050 approaches.
- In the UK, a similar cluster strategy is emerging, with a focus on developing a hydrogen cluster in the Yorkshire & Humber region, the UK’s largest industrial hub in terms of energy consumption and emissions. This region presents significant opportunities to replace natural gas with hydrogen across several industries, including glass manufacturing, steel production, and cement production. The rationale behind the development of a hydrogen cluster is that by first establishing projects which would supply a handful of large local industrial users, this may support a cost-effective hydrogen transition which can then be rolled out more broadly. There is political support in the Humber region for decarbonisation initiatives and it is hoped that by first utilising blue hydrogen, this will reduce the costs associated with the subsequent introduction of green hydrogen produced by using energy from offshore wind projects in the North Sea.
- The international approach follows a similar path, with the International Energy Agency (“**IEA**”) suggesting that industrial ports, such as those around the North Sea, the North American Gulf Coast, and China’s Pacific coastline, could become key centres for scaling up hydrogen technologies globally.

Conclusion

Undoubtedly, hydrogen is poised to play a critical role in the decarbonisation of industrial processes, with its most significant applications currently in sectors such as oil refining, ammonia production, and steel manufacturing. Both blue and green hydrogen will have a role to play, with the scale and capital needs of the industrial sector making this an appealing proposition for investors ready to move beyond R&D projects. To fully realise hydrogen's potential, continued policy support and collaboration among stakeholders will be critical. Expanding industrial clusters, improving infrastructure, and establishing clear regulatory guidelines will be essential in accelerating hydrogen adoption across sectors, paving the way for significant emissions reductions. While processes may need to evolve in the coming years, hydrogen will unlock complementary technologies, such as carbon capture and storage, and expand its deployment in more industries.

Authors


Dalia Majumder-Russell
London
Partner

Natasha Kenber
Associate
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