Europe and Asia edging ahead in global race to Green Hydrogen Technology Supremacy

This report was prepared by Fitch Solutions, using Cipher classifiers on Green Hydrogen patents

Fitch Solutions fuels better informed credit risk and strategy decisions with reliable data, insightful research and powerful analytics across global markets and macroeconomic environments.

Cipher is able to reveal the technology DNA of every company. We use machine learning to map patented technologies to companies to answer the question “who is doing what?”.

Key View

- The green hydrogen sector will see rapid technological innovation as the sector continues to scale and evolve.
- Asia, North America and Europe will lead the electrolyser technology race given their respective project pipelines, suitability for hydrogen market development and existing innovation in the sector.
- European firms have a dominant position in hydrogen project pipeline, but Asian companies leads in terms of innovation of the sector. The US underperforms as it is a notable project pipeline laggard.

The green hydrogen sector will see rapid technological innovation as the sector continues to scale and evolve.

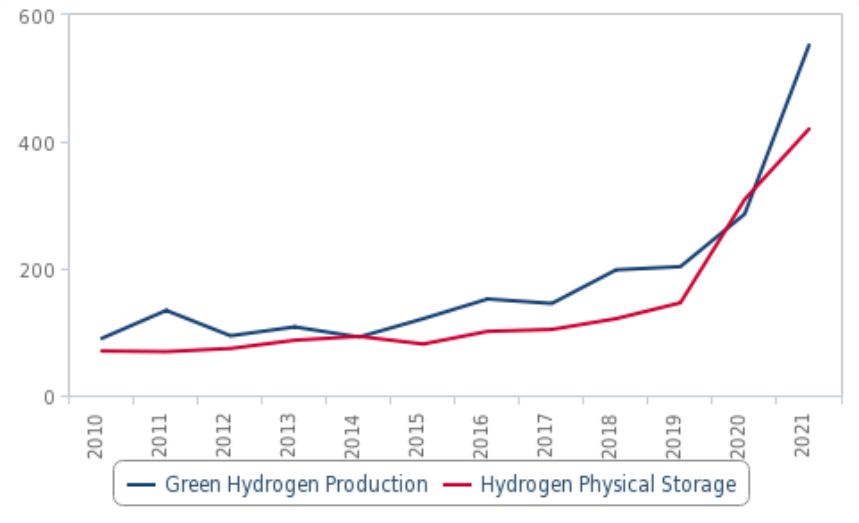
Green hydrogen is produced using renewable-based electricity and water as feedstock for an electrolyser, which splits water into its two constituents of hydrogen and oxygen. Electrolyser technology has been in industrial practices for decades and is highly understood. However, the increased flow of investment into the sector has seen a renewed focus on how the technology can be deployed.

The pipeline of hydrogen projects in the Fitch Solutions Infrastructure Key Projects Database (KPD) has increased significantly over the past year, rising from a handful of small-scale 10MW capacity projects over Q120 to over 220 commercially viable, large-scale (greater than 10-100MW+) projects by Q122 with an approximate known combined-capacity of 128GW. This growth in the sector is being driven by declining renewable energy costs, a surge in renewable generation and a global ambition to decarbonise energy intensive sectors in an effort to mitigate climate change. This has brought on a groundswell of investment not only into project development, but also into technological advancements and innovation.

At a time of rapid change within the industry, the challenge of assessing the competitive landscape centres on the lack of sufficient data on investments across green hydrogen production and hydrogen storage. Therefore, we have incorporated patent data into this research to highlight innovation specific to the sector. By doing so we are able to identify the pace of progress associated with companies through their investment into research and development and patent filing in what is still a nascent industry. As seen in the chart below, the past five years have seen a rapid increase in the the pace of company-led innovation in green hydrogen production and storing of the gas.

Rapid Increase in the pace of innovation across Green Hydrogen production & Hydrogen Storage technologies

Global - Patent Families Published 2011 - 2021



Source: Cipher, Fitch Solutions

Looking across the patent data we see clear evidence of the accelerated pace of innovation in recent years. Between 2019 and 2021 the total number of granted & pending patent classes that were published for production-based green hydrogen technology was found to be 66%, and 65% for hydrogen storage. We expect this rapid pace of innovation to continue to grow as technology and the sector evolves into a core part of global decarbonisation efforts. Despite electrolyser technology being highly established, there is not one form of design. The current industry leader is the proton exchange membrane (PEM) technology. We expect the majority of innovation in electrolyser technology to be focused on improving efficiency and reducing costs, with a particular focus on potential variations of the technology that reduce the need for high value materials. PEM devices require significant amounts of platinum and iridium and therefore advancements in electrolysers that use fewer high-cost materials are being explored.

Storing gas remains a core issue to high volume users

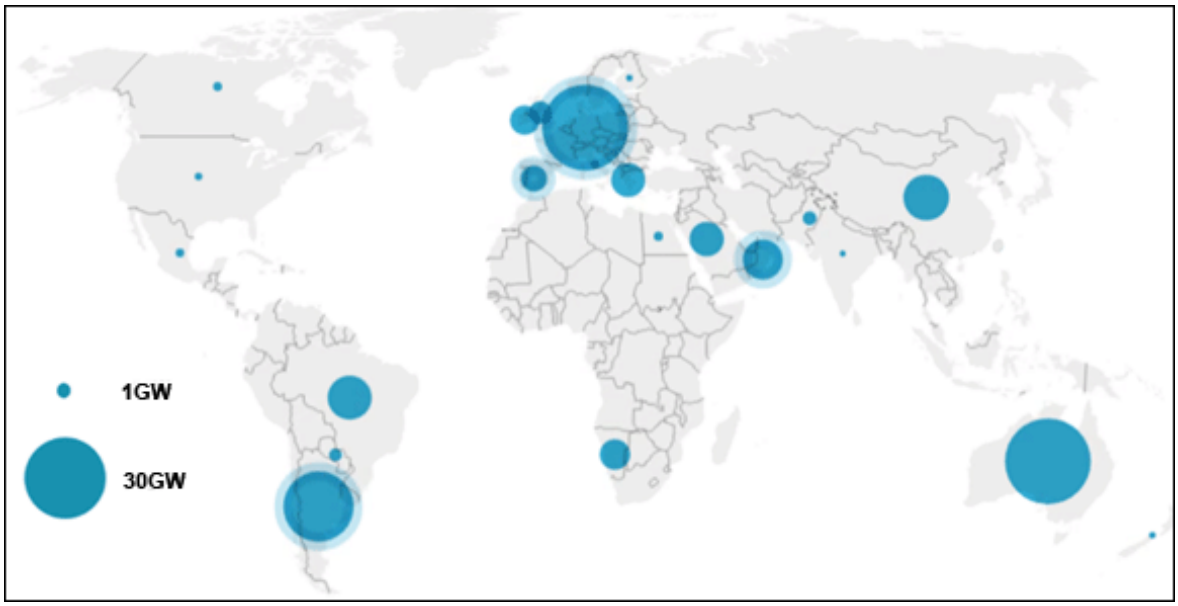
Industrial users of hydrogen that require large volumes will find themselves needing dedicated pipelines to sustain supply or the development of vast storage facilities. The level of innovation in this field has also accelerated with storage of hydrogen in either liquid or gaseous form seeing an uptick in patent activity. This includes storage as a compressed gas, cryogenically compressed and liquid hydrogen storage methods, and methods of transporting hydrogen directly into and out of the storage containers. We highlight that leading gas-handling companies across the world are investing in this area, and we expect that European and Asian companies, in particular, will move into this space. Already, major players in Western Europe's natural gas sector have announced efforts towards expanding the use of hydrogen in their operations. In 2020 we saw 11 gas infrastructure operators including **Enagás, Energinet, Fluxys Belgium, Gasunie, GRTgaz, NET4GAS, OGE, ONTRAS, Snam, Swede gas (Nordion Energi) and Teréga,**, look to explore a regional transportation and storage network. Furthermore, our research highlights that the development of localised hydrogen hubs will be a key trend in the technology's early adoption and onsite storage will be a requirement across industries. However, given the wide scope of use cases, the type of storage will vary considerably.

Electrolyser technology race apparent across three key regions

Asia, North America and Europe will lead the electrolyser technology race given their respective project pipelines, suitability for hydrogen market development and existing innovation in the sector. Our views are supported by global project pipeline growth, which is being led by Western Europe with 97 projects and Asia with 43, while Australia stands out as the single largest market in the project pipeline by count with 30 projects - the majority of which are slated for the export market. Germany and the Netherlands both account for a sizable proportion of the global production capacity project pipeline; 13GW and 10.4GW respectively. Among the global standings, these markets exhibit the second and third-largest project pipelines of hydrogen electrolyser projects. The US however, has a comparatively small pipeline with under 100MW capture in our KPD.

Global Green Capacity concentrated in several key Global Regions as markets look at Exports

Global – Green Hydrogen Pipeline, GW



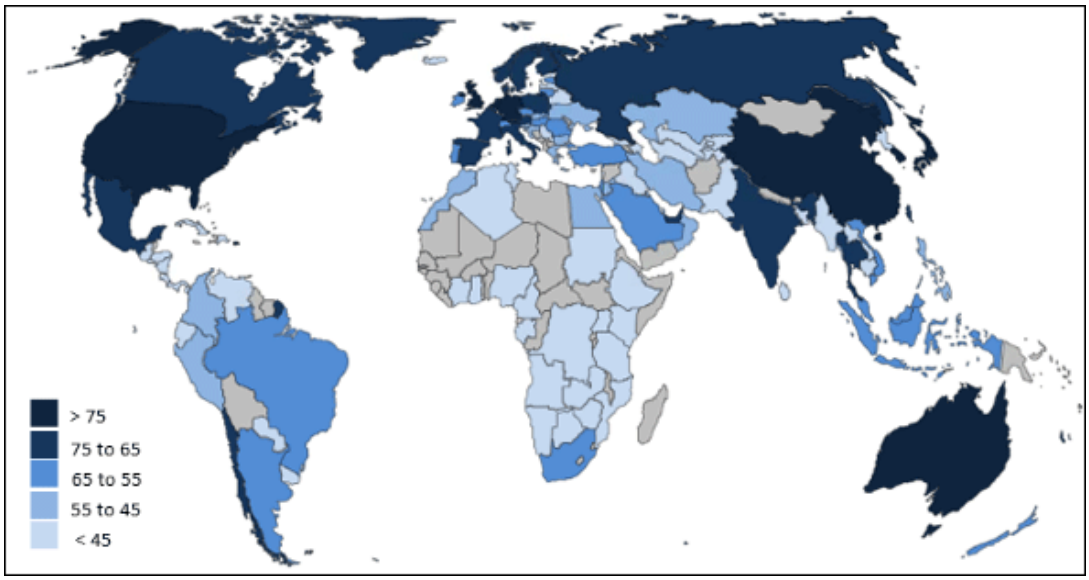
Source: Fitch Solutions Key Projects Database. Note: Bubble Size Indicates Capacity Scale

Suitability Index Supports Regionalisation of Technology

The North America and Western Europe (NAWE) region leads our global index for green hydrogen market suitability, which considers the factors which would need to be in place for a green hydrogen industry to emerge. The region holds seven of the top 10 global markets including the top two with Canada (1) and the US (2), while Germany and other European markets also rank highly. Asia Pacific continues to be an attractive region for the development of green hydrogen, with the top three markets in Asia also ranking among the top 10 global markets based on 2021 assessments - Australia (4), China (6) and South Korea (9).

Asia and Europe offering greatest concentration of Hydrogen suitability

Global – Green Hydrogen Suitability Index, global average = 46.4 (Q2-2022)

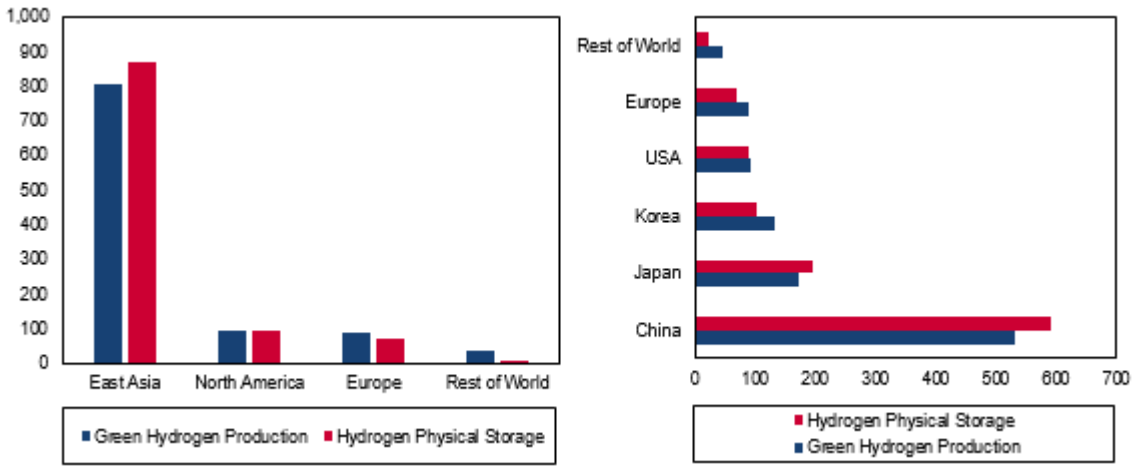


Note: Scores out of 100; higher score = more attractive market. Source: Fitch Solutions Hydrogen Index

Despite project development outside of Asia and NAWE, we do not expect to see widespread technological innovation from other regions. Many global energy market leaders are heavily investing in green hydrogen. For example, Chile, with its substantial renewable energy power capacity has ambitions to develop 25GW of green hydrogen production capacity by 2030. Russia ranks highly on our green hydrogen suitability index due to its vast industrial user potential. Middle Eastern markets, many of which are global energy players, are investing in electrolysers and developing renewables to compliment green hydrogen production. However, all these examples in their respective regions of Latin America, Eastern Europe and the Middle East lack the advanced technology companies and manufacturing capacity to compete with the established players in other key regions when it comes to electrolyser technology development.

Green Hydrogen innovation protection dominated by Asia with China, Japan and Korea as standouts

Global - Number of Patent Families with Grants by Region & Market



Source: Cipher, Fitch Solutions

Asia leads research globally with China, The Sleeping Giant

Despite the larger pipeline of hydrogen projects being worked on by European firms, we highlight that these firms are comparatively subdued in terms of innovation compared with Asian companies. Asian firms dominate the global patent creation market with China, Japan and Korea being particularly strong as outlined below. However, the companies in these markets have highly limited involvement in actual project development with limited project pipelines.

Chinese hydrogen project developments in particular have been a global laggard, however, we expect large upside risks to the current pipeline and we foresee a rapid change over the coming decade as outlined in our research. Localised policy support shifting to accelerate low carbon hydrogen production will act as a catalyst for the sector in the market, although the central government's support remains relatively quiet at this point.

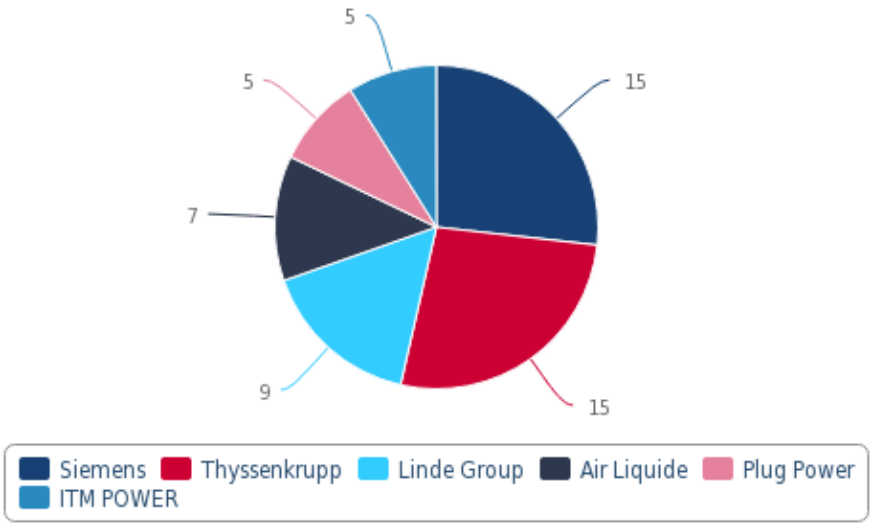
Therefore, we expect that China and other Asian markets will look to benefit from the early moves of other companies and regions in establishing the global hydrogen industry, reducing costs and developing a supply chain for hydrogen. As this happens, the Asian companies which hold a significant number of patents in the hydrogen space will pursue their own growth strategies while continuing research and development ensuring their own industries remain competitive.

We highlight that the markets in the above regions are leveraging their highly advanced industrial expertise to broaden their global footprint. While most markets in North America and Europe already have manufacturing capabilities and companies with a proven track record, we expect markets new to this space to look to expand production capabilities. Australia, for example, has a limited patent development but the world's largest electrolyser project pipeline. However, this will take time and considerable levels of investment. **Fortescue Metals** is looking to develop the market's first GW scale factory capable of delivery 2GW per annuum costing an approximate USD650mn.

European firms dominate the hydrogen project pipeline, but Asia leads in terms of innovation of the sector. Overall, European firms comprise 60% globally of the roles for hydrogen projects within our KPD including, sponsors, financiers, operators, manufacturers, constructors and consultants, highlighting the existing expertise of these firms in the sector. However, of the existing leaders in electrolyser development in the patent data, it is only **Siemens** and **Thyssenkrupp** that are also heavily involved in project development. There is minimal involvement from technology developers outside of Europe in project development.

Several key Electrolyser manufacturers leading as Project Sponsors

Leading Electrolyser Manufactures – Project Involvement by Project Count

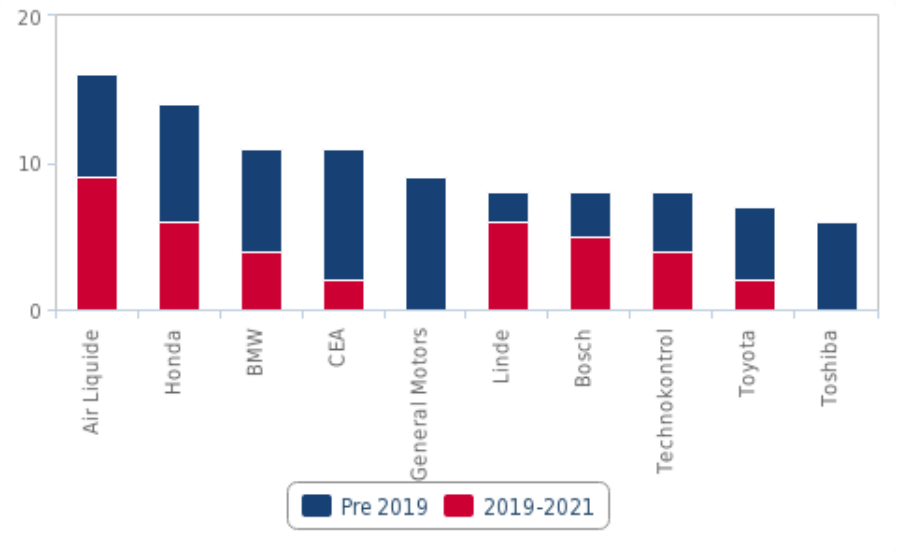


Source: Fitch Solutions Key Projects Database

Looking at patent protection in Europe, these companies remain among the most innovative across green hydrogen technology with both the greatest absolute total number of patent families and having published the most over recent years 2019 - 2021. Furthermore, **Air Liquid** and **Linde** are among the region's companies that are seeking to expand their leadership in this field by supporting technology development and leading innovation as outlined below. In contrast **ITM Power**, **Plug Power** and Thyssenkrupp are not innovating as aggressively.

Two industry leaders, Linde & Air Liquide, stay ahead amid of recent patent filling surge

Top 10 - Patent Owners in Green Hydrogen across the US & Europe



Source: Cipher, Fitch Solutions. Note: Commissariat A L'Energie Atomique = CEA

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