Hydrogen Insights

An updated perspective on hydrogen investment, market development and momentum in China

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Executive summary

Hydrogen momentum continues to grow. Since the publication of the Hydrogen Insights report in February 2021, more countries have committed to decarbonization targets and large-scale clean hydrogen projects have been announced, amounting to over ten million tons of total capacity by 2030 or about a third of total clean hydrogen demand growth expected in the next decade. For the international shipping of hydrogen, ammonia, LOHC and liquid hydrogen are the main considered vectors. While Europe and East Asia continue to lead in hydrogen, regions rich in renewables and carbon storage are stepping in to supply clean hydrogen. And China is emerging as a potential hydrogen giant: following its announcement to target net-zero emissions by 2060, plans to achieve "peak carbon" in various sectors, including aviation and steel before 2030, have been put forward and over 50 hydrogen projects have been announced.

Global momentum

Based on accelerated climate ambitions, hydrogen is accelerating its deployment as a key energy transition pillar

The commitment to decarbonization is getting stronger. The US has reentered the Paris Agreement and announced that it aims to achieve net zero long-term and 50% lower emissions by 2030, matching the EU's ambition. This means over 80% of global GDP is now located in countries that have a net-zero ambition, up from 50% at the beginning of 2021. The EU's stricter CO2 targets for 2030 have supported the increase of carbon prices to USD 55/tCO2, and the UK government has committed to signing the world's most ambitious climate change target into law: cutting 1990 emission levels by 78% by 2035. These movements, among others, have reemphasized the need for clean technologies and, in doing so, have solidified hydrogen's important position in the global fight against climate change.

Deployment and investments: announced hydrogen investments have accelerated rapidly in response to government commitments to deep decarbonization

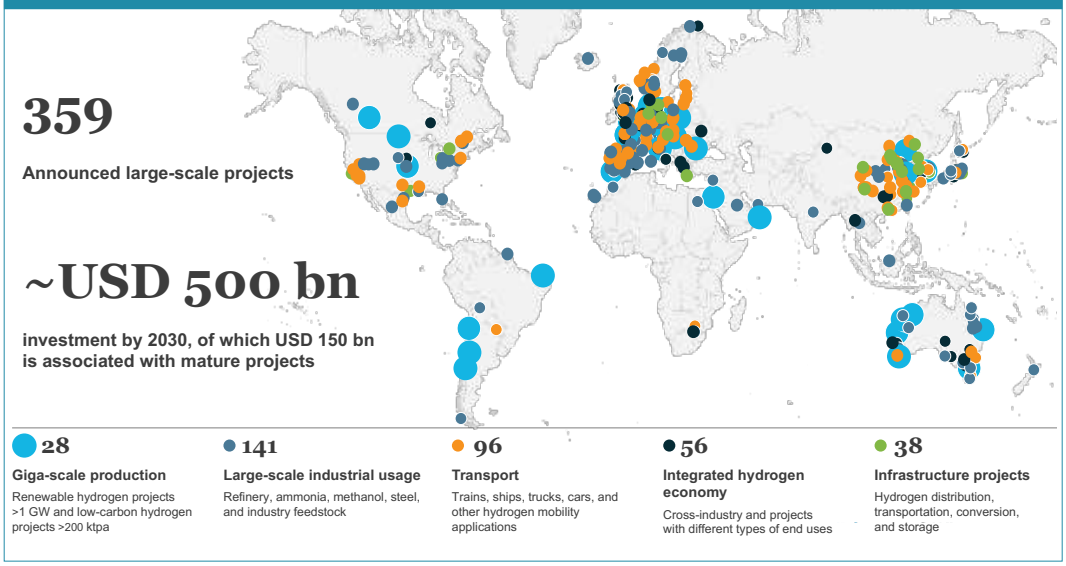
Since the last Hydrogen Insights report was published in February 2021, 131 large-scale projects have been announced globally, increasing the total to 359 hydrogen projects (see Exhibit 1). In addition, there is evidence of many other projects that are in early development and have not been publicly announced, including both large-scale projects as well R&D and demonstration projects. Total announced investment shows increasing momentum across all regions. With over 80% of new projects being located in Europe, the region remains the leader in the emerging hydrogen economy. Yet, all other regions grew faster proportionally with over 75% increase in project announcements.

It is estimated that the total associated investment through 2030 will amount to USD 500 billion. This is based on three sources:

1. USD 130 billion investment directly associated with the announced projects
2. USD 120 billion additional direct investment needed to reach government targets that exceed currently announced projects
3. USD 250 billion implied investment from OEMs and suppliers to support the required direct investment from publicly announced projects and government targets

Out of the total investment, USD 150 billion, or 30%, can be considered "mature," meaning that the investment is either in a planning stage, has passed a final investment decision, or is associated with a project that is already under construction, commissioned, or currently operational.

Exhibit 1: Global hydrogen projects and investment across the value chain



Production: announced capacity will exceed 10 million tons of hydrogen by 2030, an increase of over 60% since the latest Hydrogen Insights report

Announced clean hydrogen production capacity currently stands at 11 million tons of hydrogen by 2030, of which 50% is considered mature. This is an increase of 64% since December 2020 and over 450% since December 2019 (see Exhibit 2).

70% of the announced production capacity comes from renewable energy sources, while the other 30% is low-carbon hydrogen generated by fossil fuels combined with CCS. Production from renewable energy sources translates to about 70 GW of electrolysis capacity by 2030, which is nearly double what was announced in the last report.

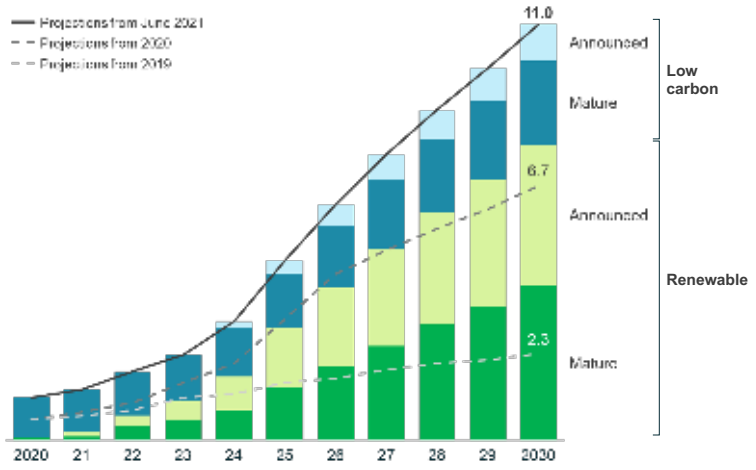
Electrolysis capacity can be generated via different energy sources and technologies. Solar and wind hybrid plants will become the main source of electricity for hydrogen production by 2030, followed by offshore wind and solar.

Distribution: trade flows between supply and demand centers are starting to form, with ammonia, LOHC and liquid hydrogen as main considered vectors

Today, almost all hydrogen is used at the location of production, but this is set to change. By 2030, roughly 30% of announced production capacity will be transported, either through ships or pipelines. The biggest exporters by announcement are Australia, Saudi Arabia, and Chile. For longer-distance transport by ship, hydrogen needs to be converted to increase its energy density. Ammonia, LOHC, and liquid hydrogen are the main considered vectors for export; however, almost half of the projects' carriers are still undecided.

Exhibit 2: Announced clean hydrogen capacity through 2030

Cumulative production capacity, Million tons p.a.



>60%
increase in capacity
announced in the past 5 months

69 GW
clean hydrogen capacity
by 2030 announced

+7.7 Mt
additional capacity
(low carbon and renewable)
announced for post-2030

End application: investment in end-use applications mainly focuses on industry feedstock and transport applications

Cumulative investments across hydrogen end-use applications amount to USD 40 billion direct announcements in 2030, or USD 130 billion if indirect investments and government commitments are also considered. Looking across sectors, most capital flows into hydrogen for use as industry feedstock (USD 20 billion), followed by transportation (USD 16 billion, including investment in synfuel production plants, hydrogen refueling stations, and large-scale vehicle manufacturing projects – if announced), power generation (USD 2 billion), and residential and industrial heating (less than USD 1 billion).

Insights on China

China has set ambitious targets: net zero by 2060 and peak carbon emissions in key sectors before 2030

In September 2020, China pledged to reach peak carbon emissions before 2030 and to achieve carbon neutrality by 2060, a major step to limit climate change. In order to achieve this, China has developed ambitious targets across industries. For example, in the transportation sector, last October the Chinese Society of Automotive Engineering published the New Energy Vehicle Industry Development Plan (2021-2035), which aims to improve the EV share of all new energy vehicles to around 95% by 2035 and targets 1 million FCEVs and 2,000 hydrogen refueling stations. Moreover, China is accelerating the energy transition by increasing the total installed capacity of solar and wind to 1,200 GW by 2030, and it is expected that hydrogen could comprise 10% of the energy share by 2050. Drivers of this uptake are numerous, including net-zero ambitions, energy security, and economic growth.

Deployment and investments: more than 50 large-scale hydrogen projects have been announced, resulting in over USD 180 billion in committed or announced investments

53 hydrogen projects have been publicly announced in China, of which 50% are linked to transport applications. Key announced projects include Sinopec's ambition to build 1,000 refueling stations in the next 5 years, and the commissioning of a 200 MW PV-connected hydrogen plant in the Ningxia region.

The total estimated investment amounts to USD 180 billion:

1. USD 20 billion in direct investment has been announced

2. USD 75 billion in additional investment will be required to reach government ambitions

3. USD 85 billion in indirect investment will be needed from OEMs and suppliers

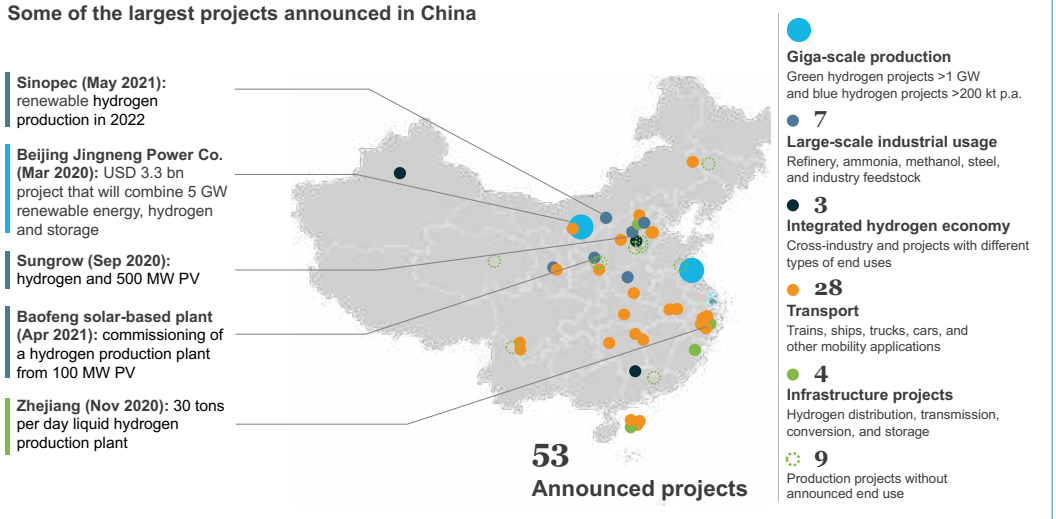
To support investment, the Chinese government has made USD 20 billion of public funding available to hydrogen projects. Around USD 17 billion of total investments in China are considered mature, of which 75% have been announced by fuel cell and FCEV manufacturers.

Production: renewable hydrogen will play a major role in the growth of hydrogen production in China

Multiple pathways exist to decarbonize hydrogen production in China. Comparing production costs across technologies, electrolysis at today's LCOEs is already competitive with low carbon production technology (coal gasification in combination with CCS). By 2030, electrolysis will become the lowest-cost low-carbon production technology in all locations.

Multiple factors will drive the adoption of renewable hydrogen: First, it will benefit from China's scale-up in renewable energy production from a total capacity of 500 GW in 2020 to 1,200 GW by 2030. Moreover, China has committed to developing a high-quality transmission grid and expanding its storage capacity to ensure the flexibility needed to increase the share of energy produced by

Exhibit 3: Hydrogen projects across the value chain in China



renewables. Combined with falling electrolysis capex costs, this can lead to renewable hydrogen production costs as low as USD 2.4/kg in optimal production locations today. By 2030, the cost for electrolysis could significantly decrease to USD 1.7/kg in cost-optimal locations. The transition to renewable hydrogen in China has already started, with the vast majority of announced projects using renewable energy as their source. They account for one million tons of hydrogen, or 11 GW of electrolysis capacity.

For low carbon hydrogen production, CCS technologies can be used to capture up to 98% of emitted CO2 from coal gasification, making it a viable clean alternative. However, as production costs for coal gasification plus CCS are currently USD 2.8/kg and evolving to USD 2.5/kg by 2030; this would make coal-based low carbon hydrogen production more expensive than electrolysis in optimal production locations.

Distribution: China will need to connect renewable-rich regions (West) to high hydrogen demand areas (coast)

Looking at China's key hydrogen markets, such as transportation and steel production, most demand will come from coastal areas in the East. However, China's renewable hydrogen supply centers are mainly located in the West, where there is abundant solar and wind capacity that could be taken advantage of. This implies a supply and demand gap that needs to be closed via two possible solutions: 1) distribution of Chinese hydrogen from the West to coastal and Northern China or 2) import of hydrogen from other countries to coastal and Northern China. While production costs in potential export markets such as Australia, Saudi Arabia, and Chile are lower than in Western China, liquification and shipping costs make imported hydrogen less competitive (50% more expensive) compared to local production. As such, China is likely to supply its own hydrogen needs.

However, given higher production costs, China is currently not competitively positioned to export hydrogen to other countries as compared to Australia, Saudi Arabia, and Chile.

End application: the vast majority of China›s clean hydrogen production projects are for transport end use

While the majority of projects have not announced an end use, out of those that have, 50% are focused on transport. This supports China's decision to make hydrogen a focal point in its decarbonization strategy for the transportation sector. As of today, most Chinese commercial vehicle players already have some level of entry into the FCEV space, mainly in buses and light trucks; however, this is likely to increase in parallel with the growth of hydrogen and expand to other types of vehicles in the near future.

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As this executive summary illustrates, momentum has continued to build since our Hydrogen Insights publication in February. The Hydrogen Insights update is based on several sources of material: 1) project announcements tracked by the Hydrogen Insights team across major renewable energy fora, 2) project data survey and validation by Hydrogen Council members and sister hydrogen associations, and 3) expert interviews. All the individual projects included in the Hydrogen Insights project tracker can be traced back to concrete project announcements.

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