Hydrogen Value Chain Trends and Challenges

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Abstract

In Europe, since the formulation of the European Hydrogen Strategy, a number of policies and projects have been initiated to establish a multilateral hydrogen value chain. This unprecedented large-scale initiative faces many issues that we can learn from. Meanwhile, North America and China are also making great strides with increased investment in the hydrogen value chain, supported by their industrial policies. As Japan is also attempting to create a hydrogen value chain for the sake of climate action, and with the expectation of making it a future competitive industry, it is worth analyzing the experiences in these countries. Against this background, this report first outlines the hydrogen development plan in Europe. Second, it discusses the various challenges, including competition with those in North America and China. Finally, it tries to deliver implications for Japan.

Key words: Hydrogen, Value Chain, Trends, Issues, Investment

1. Background

An energy transformation (hereinafter "GX") is taking place in the world on an unprecedented scale in the form of decarbonization. Its implementation will require substantial investment in order to convert the infrastructure. Electric power generated from renewable energies (hereinafter "renewables") will become a major energy source, but hydrogen will complement that as an important medium that can be utilized for the storage and transport of energy.

Europe has pioneered the introduction of renewables, and it is also striving to construct a strategy to systematically promote hydrogen. However, the change in circumstances since Russia's invasion of Ukraine in 2022 has brought about major changes to Europe's GX efforts, and hydrogen is also being affected. In light of that, this report presents an outline of the circumstances and challenges of Europe's hydrogen value chain construction, while also considering the challenges to constructing a hydrogen value chain in Japan, through comparisons with the situations in the US and China.

2. Hydrogen's characteristics

2.1 Characteristics

Hydrogen, which is attracting attention amid GX, has the following characteristics:

- It can be produced from electric power generated by renewables, is a multi-vector energy source that can be converted into various fuels as well as electricity, and does not emit CO_2 when used
- It can be stored for long periods without energy loss during storage
- It serves as a medium for transporting renewables over long distances, and as an alternative to fossil fuels utilized to meet heat demand
- It is a gas at room temperature and has a low energy density by volume, but it can also be transported and utilized by converting it into a liquid or ammonia and synthetic fuels, etc.

In addition, hydrogen has multifaceted roles and dimensions, and there are competing energy technologies for each.

- Fuel for producing heat/ Fossil fuels (+CCUS), biofuels
- Transport medium for renewables/ Power lines
- Storage of renewables/ Storage batteries
- Raw material for chemical goods/ Fossil fuels (+CCUS), biofuels
- As a target for investment, PV and wind power are also competitors

2.2 Production cost

In the case of green hydrogen, the cost of the electric power used for electrolysis accounts for 70% of the cost, so the price of hydrogen is influenced by electricity prices. In addition, compared to fossil fuels, the initial investment is large and the rate of return on investment is low (12% or lower). In order to reduce the initial investment, it will be necessary to lift the operating

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rates of electrolysis equipment. Currently, because hydrogen is more expensive than fossil fuels, support in the form of environmental premiums or subsidies is needed. Going forward, the price of hydrogen can be expected to decrease as a result of larger facilities and improved efficiency, increases in the supply of renewables, increases in the quantity of hydrogen in circulation, and other developments.

3. Trends in Europe

3.1 Constructing strategies and frameworks

Japan formulated the world's first hydrogen strategy in 2017. Europe's hydrogen strategy was formulated in 2020, later than Japan's, but subsequently, Europe has begun to move rapidly and is seeking to promote hydrogen by establishing various organizational entities. Hydrogen strategies are also being constructed in respective countries, and an emphasis is being placed on developing supply, transport, and utilization technologies as components for GX.

Following the 2022 invasion of Ukraine, The EU, mainly Germany, has accelerated efforts to reduce its dependence on fossil fuels from Russia, and the EU, under the REPowerEU plan, stepped up its shift to renewables and advancement of its hydrogen strategy.

Table 1 Europe's hydrogen-related policies and organizational

Year	Policy / Organizational Entity
2018	European Hydrogen Initiative
2019	European Green Hydrogen Roadmap
2020	European Hydrogen Backbone (EHB) initiative established 2x40 GW Hydrogen Initiative EC: "European Hydrogen Strategy" Germany: "National Hydrogen Strategy" Important Project of Common European Interest (IPCEI) established
2021	Germany: H2Global established
2022	REPowerEU -Hydrogen Accelerator Clean Hydrogen Partnership established
2023	EU: Green Deal Industrial Plan, Renewable Energies Directive European Hydrogen Bank established Germany: Hydrogen strategy revised ISO/TC 197 (GHG calculation method for hydrogen) issued
2024	EU: Net-Zero Industry Act, Critical Raw Materials Act Germany: Hydrogen import strategy

However, the rapid conversion from Russian fuels led to inflation, including due to soaring energy costs, and so moves to postpone or halt projects, including wind and solar projects, are surfacing due to their profitability deteriorating in the face of the cost increases. In addition, as a result of powerful industrial policies in the US and China, competition is increasing, particularly in renewables-related industries, and competition to attract investment is also intensifying. Nevertheless, this is not to suggest Europe will withdraw from GX—in the long term, it is steadily pursuing GX and moving toward building a hydrogen value chain.

3.2 Constructing a value chain

Wind conditions in high altitude regions of Europe are good, and on the Iberian Peninsula potential renewable capacity exceeds demand. On the other hand, in countries where there is a large demand, such as Germany, there are shortfalls, and so overall, like Japan, it is necessary to import energy from outside the region. Furthermore, even within the region, heavy industries and other industries for which shifting from fossil fuels to electricity is said to be difficult are congregated in center of Europe and particularly in Southern Germany, meaning there is a large number of potential hydrogen consumers located there. It will therefore be necessary to transport hydrogen from locations in the vicinity of Europe to center of Europe, and so five hydrogen corridors are being planned. One is a plan to transport hydrogen from the African continent, a neighboring continent that also has a large potential renewable capacity, via a seabed pipeline. The Netherlands has come out with a hydrogen hub concept for importing by sea and is planning to upgrade ports and supply hydrogen to within the European continent via pipelines. In addition to this, the EU and respective European countries are undertaking diplomatic efforts to secure imports from regions with large potential renewable capacity, such as Canada, Australia, the Middle East, and Africa.

There is a large amount of heating demand in Europe, and inter-seasonal gaps in demand for natural gas for heating purposes are managed using underground storage. If hydrogen is used as an alternative, similar underground storage in the base rock layer is being planned, but this will also fulfill a role in absorbing fluctuations in renewables for which output varies (so-called variable renewable energy; hereinafter "VRE"). In 2021 there was a lengthy period during which wind conditions deteriorated, and this was covered using gas-fired power generation and other sources. Addressing VRE fluctuations is one of the roles that will become increasingly important going forward.

Where demand is concerned, the intention is to switch to

hydrogen to cover demand where electrification is difficult, and the steel division is developing hydrogen reduction ironmaking technology. Regarding transportation, there are plans to install infrastructure such as hydrogen stations at 200 km intervals along the roads in the Trans-European Transport Network towards increasing the adoption of fuel cell-powered long-haul trucks.

Additionally, focused support is being provided for new, GX-related industries such as electrolysis equipment for hydrogen production, and industry-nurturing policies are being pursued for regional production, industrial transformation, and job retention.

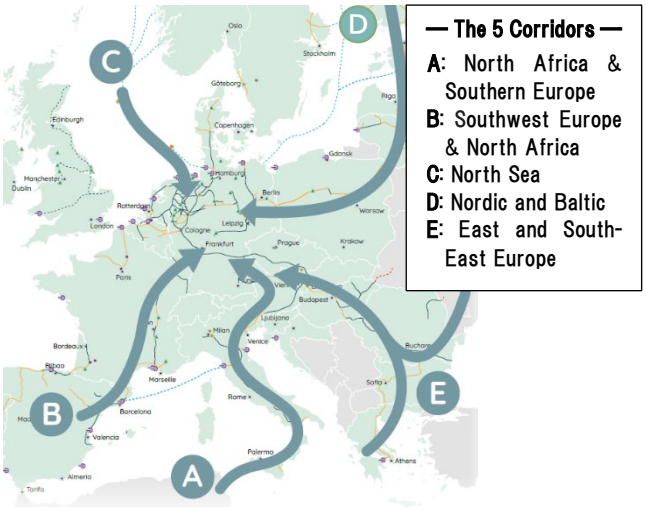

Fig. 1 Five hydrogen pipeline corridors
(Source: EHB2022, edited by the author)

3.3 Promotion policies and system construction

Support is being ramped up—in 2020, the Important Projects of Common European Interest (IPCEI) was established in order to support GX, including hydrogen, and then in 2023, the European Hydrogen Bank was set up to encourage investment in hydrogen. Additionally, systems such as the EU Emissions Trading System, carbon taxes, and the Renewable Energies Directive are having the effect of lifting the environmental value of hydrogen, and vigorous efforts are underway to construct systems and create benchmarks for that.

4. Europe's challenges

GX is a procedure for remodeling the major energy value chains that have been constructed up to now, from upstream to downstream. Because the geographical flows of energy will change, the construction will require enormous investment and a lengthy timespan. Investment from the private sector, not just governments, will be essential, and policies for attracting investment are needed.

4.1 Massive infrastructure investment needs, and rapid advances by North America and China

The hydrogen value chain will require massive infrastructure investment, from production through to transport, delivery, and use modification. According to Hydrogen Insights 2024, Europe has the largest number of announced hydrogen projects in the world, with total investment reaching 199 billion US dollars by 2030 (as of May 2024), followed by Latin America at 107 billion US dollars and North America at 96 billion US dollars. However, in the most recent six-month period (October 2023 to May 2024) Europe's investment in new projects was low, while in North America, India, China, and Latin America, the scale of investment increased.

There are fears of a slowdown in investment, including in relation

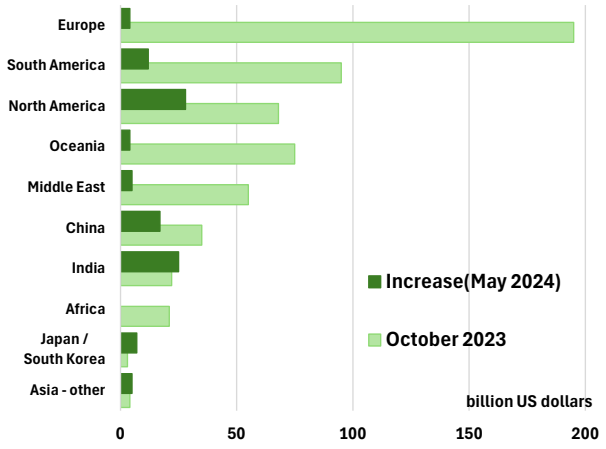

Fig. 2 Investment amount of announced hydrogen projects (from Hydrogen Insight, edited by the author)

to renewables, in Europe. One backdrop to this is competition with policies to promote GX investment in regions outside Europe. The US' incentives, such as its clear and effective Inflation Reduction Act (hereinafter "IRA"), and China's strong industrial policy, driving costs down thanks to deployment at scale, are proving effective, while Japan's contract-for-difference instruments are also effective for driving offtake.

In addition, one reason the US and China have been moving rapidly ahead with hydrogen projects is that their policy decisions are concluded domestically. In contrast to this, in Europe, it is a two-tiered process involving consensual decisions by the EU countries and each country's policies. Because value systems also differ depending on the country, promoting policies takes time.

In North America, hydrogen production projects are advancing the most, with final investment decisions having been reached on projects totaling 2.4 million t/year by 2030 (75% is low-carbon hydrogen, not green hydrogen, however). Even in China, final investment decisions total 1.4 million t/year (with green hydrogen

accounting for 95%). In Europe, however, final investment decisions remain at 0.3 million t/year. In Europe, a large proportion of investment is in projects at the early phase of development (pilots), but in North America, there is a lot of investment in large-scale projects at the commercial stage, and so a large percentage of projects have reached the final investment decision.

China accounts for 66% of the world's current cumulative capacity of electrolysis equipment, at 1,150MW, followed by Europe at 14% and North America at 9%. However, because a large amount of hydrogen in North America is low-carbon hydrogen arising from fossil fuels + CCS, North America accounts for 52% of hydrogen producing capacity, followed by China at 30% and Europe at 8%. Europe has been investing in building a renewables industry, but the US' and China's industrial policies are powerful, so Europe will face fierce competition in the future also.

4.2 Profitability being undermined by inflation

GX requires substantial investment, but soaring energy prices in Europe since 2022 have eroded the private sector's capacity for investing and are also having an impact on public finances.

Rising energy costs are driving inflation, and the soaring cost of materials is undermining the profitability of projects, leading to cases in which projects are having to be deferred or halted.

4.3 Uncertainty surrounding projects

In the future, increases in scale and increases in supplies of renewable electric power are expected to bring down costs, but there are also predictions that this progress will be slow. Projects' earnings are deteriorating, and a loss of certainty around the offtake outlook is occurring. On the demand side, the uncertainty surrounding supply periods, quantities, and prices is making investment decisions difficult.

The EU Emissions Trading System, carbon taxes, and the Renewable Energies Directive can enhance the value of hydrogen, but the extent and timing are uncertain factors.

4.4 The renewables supply hurdle

Unless renewables expand, the cost of green hydrogen will not decline. However, due to the barriers created by regulations, procedures, and other factors a slowdown in the growth of renewables is also occurring. Transmission grid enhancements are not keeping pace, and in more than a few instances, renewable power generation facilities are still awaiting connection.

Given the high level of uncertainty surrounding green hydrogen supply in particular, in the US, for example, the intention is to position blue hydrogen produced from fossil fuels with carbon capture at the center of distribution for the time being, and then pursue a gradual shift to green hydrogen.

5. Considerations

I have undertaken a comparison between the circumstances in Europe, which has been engaging in building a hydrogen value chain, and other regions, and have sorted through the various challenges. Based on this, I will consider the implications for Japan, which is likewise moving to build a hydrogen value chain.

5.1 Policies that are strongly conscious of international industrial competition

Competition is intensifying as a result of **international** industrial protectionism. Under these circumstances, GX that curbs energy costs while preserving one's own country's competitiveness, will be needed. In Europe, the so-called "Draghi report" points out that Europe needs policies and investment that are strongly conscious of **international** industrial competition. With green hydrogen, for which cost reductions are not advancing, it is difficult to win demand from companies exposed to strong competition. A strategy of securing distribution with relatively low priced low-carbon hydrogen initially, and then gradually switching to green hydrogen subsequently, as the US is doing, would likely prove effective in Japan also.

5.2 Selecting means of transport based on geography

In Europe, which I have presented a general overview of, there is a large-scale demand in the central part of the continent. While I did not discuss this in detail, because the US and China are also continental countries, they are moving ahead with supply via land-based pipelines. Japan, on the other hand, is long and narrow and surrounded by sea, and because many of its industrial sites and habitable flat land are located in coastal areas, areas of large-scale demand are concentrated in coastal areas. Conceivably, much of Japan's hydrogen supply will be imported, and given also that marine transport will be Japan's core means of transporting hydrogen, it would be effective for the country to focus on building a marine transport network.

5.3 Making investments efficient

Transforming energy chains requires a massive investment. It is not as though capital is abundant, so efficient investment that has assessed effective chains is demanded. In addition, ideally, exporter countries will undertake development and export their hydrogen using their own funds. Conceivably, Japan will rely on imports to cover a greater proportion of its hydrogen needs than

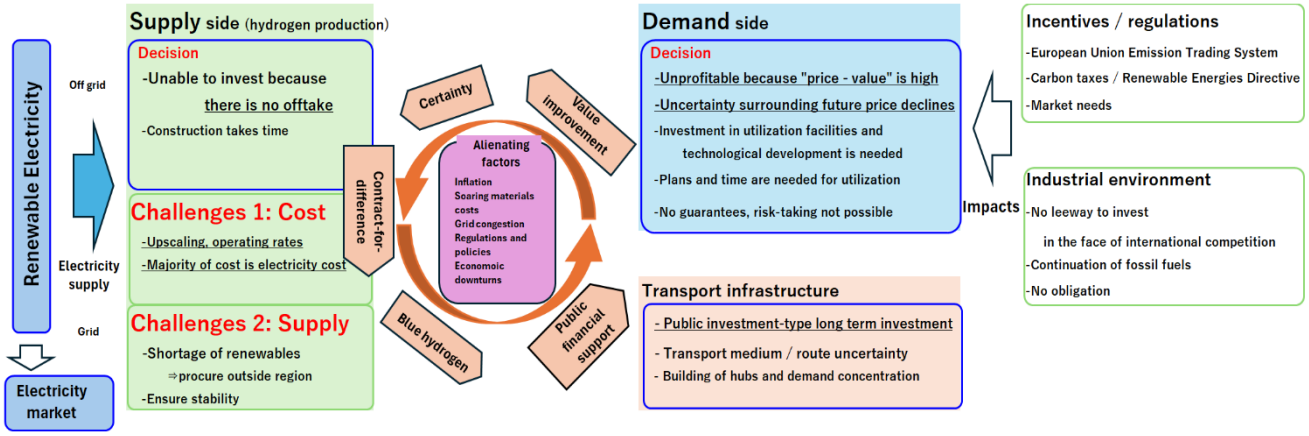

Fig. 3 Cause and effect of hydrogen market formation in GX

Europe will. Consequently, international marine distribution for hydrogen will need to be established, and it will be essential to build networks with countries that have export potential. Furthermore, because expansion in the hydrogen market can be expected to result in supply and prices stabilizing, building an international network that includes the demand side will likely prove effective also. If it is possible to strengthen ties, including mutual economic benefits, then even better.

5.4 Overcoming cause and effect in supply and demand

In the hydrogen market, because the supply side cannot invest if there is no offtake, demand creation is said to be important. From the other, demand side perspective, unless the cost of hydrogen declines, it is not possible to invest in utilization facilities. In other words, a “chicken and egg” relationship exists, and because both are in a reciprocal causative relationship making the decision to sever that is difficult. This is the largest factor contributing to hardship in hydrogen investment. In addition, there is also significant uncertainty in the long lead times that accompany facility construction. Contract-for-difference support, FIT, and other schemes are accompanied by government (ultimately citizens’) expenditure, but they are effective measures for enhancing the certainty of investment. Because the prolonging of support increases the burden, there are measures in which rapid market growth is desirable. In policies, it is undoubtedly effective not just to set goals but also to resolve risks and to have four-dimensional roadmaps that give meaning to milestones. It is important to create a virtuous cycle on both the supply and demand sides and to ensure that market formation continues without interruption.

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