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Re-examining Japan's Hydrogen Strategy

Moving Beyond the "Hydrogen Society" Fantasy

September 2022

The English version of the report is a preliminary and partial translation of the Japanese original. Chapters translated into English are marked with an asterisk in the contents page.

Acknowledgements

We would like to express our sincere gratitude to the many energy experts who contributed to the preparation of this report.

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About Renewable Energy Institute

Renewable Energy Institute is a non-profit think tank which aims to build a sustainable, rich society based on renewable energy. It was established in August 2011, in the aftermath of the Fukushima Daiichi Nuclear Power Plant accident, by its founder Mr. Son Masayoshi, Chairman & CEO of SoftBank Corp., with his own resources.

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Introduction

Faced with an increasingly severe climate crisis, the international community has accelerated efforts to decarbonize the economy and society. This coupled with a worsening energy crisis caused by Russia's invasion of Ukraine, launched in February 2022, has made the urgency even greater to improve energy efficiency and transition to more affordable and more stable renewable energy in order to move away from dependency on fossil fuels, which are beset by geographically uneven distribution, unstable supply, and dramatic price fluctuation. The EU, which has been highly dependent on Russia for energy, has decided to undertake a strategy of increasing the share of renewables in the power sector to 69% by 2030.

This increase in momentum to move away from fossil fuels has impacted countries' hydrogen strategies. As fossil fuel prices continue to surge, momentum has grown to avoid fossil fuel-dependent gray and blue hydrogen and develop and utilize renewable-based green hydrogen, which is independent of fossil fuels and increasingly more cost-effective. The scope of applications where energy demands can be met with electrification has grown, and the range of areas that need hydrogen have decreased as the transition to a circular economy moves forward. This has led to a common understanding worldwide that hydrogen should be limited to applications where it would be difficult to achieve decarbonization with other methods.

In 2017 the Japanese government became the first in the world to formulate a national hydrogen strategy, declaring that "Japan is in a good position to take on the challenge of bringing about innovation ahead of other countries and should lead the globe in hydrogen use." However, five years later Japan has performed far below its main goal of increasing uptake of fuel cells and fuel cell vehicles, and the hydrogen stations built across the country have seen little use. Japan's efforts in producing green hydrogen needed to achieve a decarbonized society have fallen behind those of European countries, China, and other nations. The Ministry of Economy, Trade and Industry has been forced to admit Japan is behind in development of electrolysers required for producing green hydrogen. Differences in renewable power costs between Japan and other countries are still considerable — another factor impacting green hydrogen prices.

The 2017 Basic Hydrogen Strategy is misguided, both in terms of what hydrogen is used for and how it is produced. It lays out a vision of a "hydrogen society where hydrogen is used in every sector" and promotes building a large-scale supply chain without knowing where and how much hydrogen demand actually exists. Moreover, it promotes the use of gray hydrogen, which does not contribute to emission reductions. Such a strategy must be rectified without delay.

The government's strategy neglects green hydrogen and prioritizes fossil fuel-derived gray and blue hydrogen. It neglects the development of renewable energy sources, reflecting the government's skewed energy strategy that has set low targets for the deployment of renewables for both 2030 and 2050.

What is needed now is to rebuild Japan's decarbonization strategy and re-examine the hydrogen strategy it is part of. Japan needs to clearly define the applications where hydrogen is truly needed to achieve decarbonization and develop a strategy for supplying green hydrogen from within and outside Japan for that purpose. Even if blue hydrogen is used as part of the process to transition to green hydrogen, it must be in compliance with international emissions standards. Rebuilding the strategy in this way would enable Japanese companies to spread the technologies across the globe they have developed through using, distributing, and producing hydrogen so far.

This report will look at global trends in hydrogen use and production, examine other countries' strategies, identify problems in the Japanese government's strategy, and present an argument for rebuilding the strategy.

Chapter 4. Issues with Japan's Hydrogen Strategy and Direction for Rebuilding

The Japanese government formulated its Basic Hydrogen Strategy in December 2017. One of the first countries to have a national hydrogen strategy, Japan took the global lead in realizing a hydrogen society. Three years earlier in 2014, the government had created the Strategic Roadmap for Hydrogen and Fuel Cells. The roadmap was revised in 2016 and again in 2019 after the Basic Hydrogen Strategy was formulated.

This shows that the Japanese government's hydrogen initiatives clearly started ahead of other countries. However, whether these initiatives are compatible with and leading today's global movement towards 2050 decarbonization is a separate issue to be assessed.

In October 2020, Prime Minister Yoshihide Suga declared that Japan would achieve carbon neutrality by 2050. In April 2021, he increased Japan's 2030 greenhouse gas (GHG) emission targets. The 6th Strategic Energy Plan formulated in October 2021 states that Japan would aim to "achieve carbon neutrality through realizing a hydrogen society" and that it would "revise the Basic Hydrogen Strategy in light of the role of hydrogen in the age of carbon neutrality." However, the government has yet to present a concrete schedule for the revising strategy and continues to repeat the same initiatives and policies as before, even in the interim report (May 2022) for the Clean Energy Strategy.

In contrast, the hydrogen strategies formulated by the EU and European countries mentioned in Chapter 3 are truly strategies for the carbon neutrality era. Despite being one of the first national governments to launch hydrogen initiatives, the Japanese government has yet to establish a hydrogen strategy for a decarbonized society. And it is building a large-scale supply chain, even though it has no energy strategy for decarbonization or a clear notion of what areas hydrogen will really be needed.

Japan is falling behind Europe, China, and other countries in the domestic production of green hydrogen, which plays a crucial role in overcoming today's critical challenges of decarbonization and energy security. This delay is the result of its strategy that prioritizes gray and blue hydrogen which have no (or an unclear) impact on reducing emissions and relies largely on importing that hydrogen.

Another issue that needs to be pointed out is that the prioritization of fossil fuel-based hydrogen and the lag in developing green hydrogen is not only due to its hydrogen strategy. It also reflects the government's energy policy that has taken a lackluster approach to the development of renewable power sources. Europe will be able to take the lead in green hydrogen development as it is projected to generate nearly 70% of electricity from renewable energy sources by 2030 at less than half the cost of Japan.

The following presents an overview of the initiatives taken since the first Strategic Roadmap for Hydrogen and Fuel Cells was formulated in 2014 and points out the following three issues:

1. Selection of low-priority applications
2. Prioritization of fossil fuel-based gray and blue hydrogen
3. Significant lag in domestic green hydrogen production

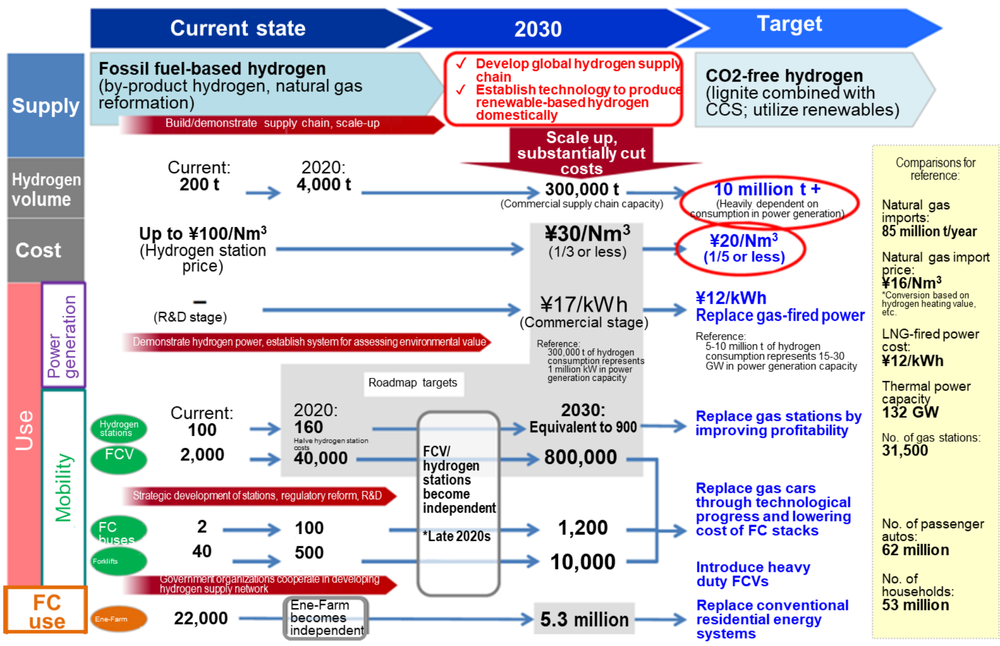
1. Selection of Low-Priority Applications

70% of the 10-year budget is spent on “bad ideas”

As mentioned in Chapter 2, areas with no other means of decarbonization should take priority for hydrogen use. Hydrogen should not be used in areas where emissions can be reduced with more efficient and economical means, such as with direct use of renewable energy or heat pumps; nor should they be used for low-priority applications categorized as “bad ideas” as defined in Agora Energiewende’s report “12 Insights on Hydrogen” (2021). Prime examples of such areas are passenger automobiles, which have strong options such as electrification, and cogeneration systems (i.e., combining heat and power) in individual buildings that can use heat pumps. However, Japan’s hydrogen strategy places “bad idea” applications as its main focus. And while the strategy has been revised somewhat, “bad ideas” continue to play the central role.

The 2017 Basic Hydrogen Strategy reads more like a fuel cell strategy. Its main theme consists of facilitating cogeneration of residential fuel cell systems (nicknamed “Ene-Farm”) and fuel cell vehicles (FCV), and expanding hydrogen stations to create a supporting infrastructure in order to meet initial hydrogen demand. The text of the strategy does mention the use of hydrogen in power generation and the industrial sector, but 80%[29] of the content related to applications is about FCs and FCVs. Most of the examples of use in the scenarios presented in the summary that was released at the same time are applications of FCs.[1]

Figure 10. Scenarios in the Basic Hydrogen Strategy



Source: “Basic Hydrogen Strategy Summary,” METI (December 2017), translated into English by REI. https://warp.da.ndl.go.jp/info:ndljp/pid/11049177/www.meti.go.jp/press/2017/12/20171226002/20171226002.html

29. Six of the seven and a half pages on applications are about FCVs and FCs.

As mentioned above, the government formulated and revised the Strategic Roadmap for Hydrogen and Fuel Cells before developing the Basic Hydrogen Strategy. Considering this, it is not surprising that the Basic Hydrogen Strategy focuses on the development and use of FCs. And taking into account the fact that Japanese companies have been trailblazers in product development in the field, it is understandable that the initial strategy focused on fuel cells. But the problem is that this skewed strategy remains unchanged to this day.

The 2021 6th Strategic Energy Plan[2] indicates the areas where initiatives should be strengthened in order to grow demand, stating: “In the coming the age of carbon neutrality, hydrogen shows promise to contribute to a wide range of fields, including decarbonization of heat which is difficult to electrify, elimination of emissions of power sources, decarbonization of the transportation and industrial sectors, manufacture of synthetic fuels and synthetic methane, and efficient use of renewable energy.”

Some of the areas where the Strategic Energy Plan identifies as areas where efforts need to be accelerated correspond to “no-regret” applications, such as hydrogen based steelmaking, using hydrogen for maritime shipping and aviation. However, it continues to reaffirm the necessity to “both support the introduction and further expansion of FCVs, and the strategic development of hydrogen stations” and states that Japan will pursue the promotion and expansion of “commercialized residential fuel cells ahead of other countries.”

Looking at changes in government spending such as granted subsidies makes it clear what it has focused on in its hydrogen strategy. Figure 11 indicates changes in the 10-year hydrogen budget of the Ministry of Economy, Trade and Industry (METI) and Ministry of the Environment (MOE) by application and amount. The annual budget is 40 – 70 billion JPY and the total for 10 years comes to about 460 billion JPY (the Ministry of Land, Infrastructure, Transport and Tourism and local governments also have their own hydrogen budgets). The budget for FCs, FCVs, and hydrogen stations for the five years from fiscal 2012 to 2016 was particularly high. Since then, they have made up about half the budget. Seventy percent of the 10-year total was used in “bad idea” applications described in Chapter 2.

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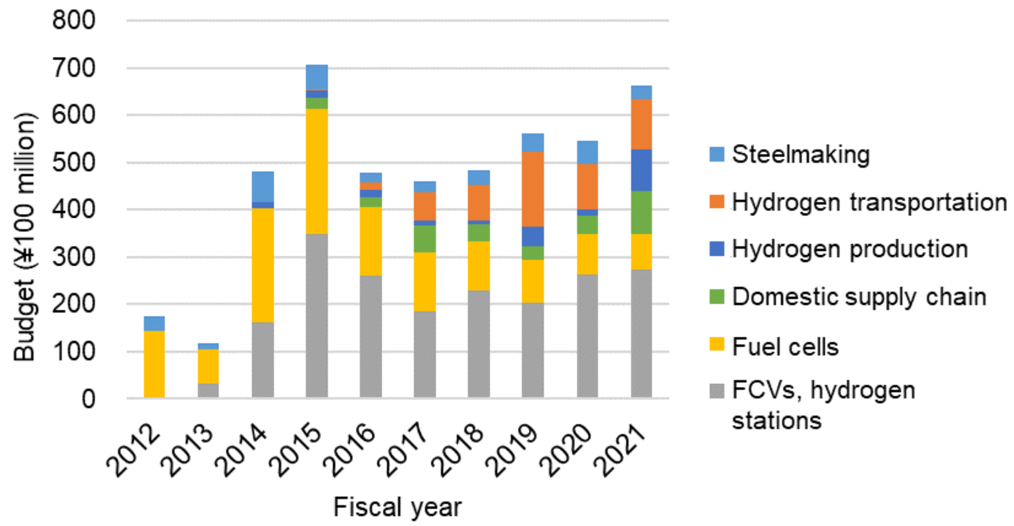
30. “6th Strategic Energy Plan” (October 22, 2021 Cabinet Decision) p. 79

Figure 11. Changes in Hydrogen Budget by Application



Source: Totaled by Renewable Energy Institute based on METI and MOE review sheets
https://www.meti.go.jp/information_2/publicoffer/review.html
https://www.env.go.jp/guide/budget/spv_eff/review.html

Failure of Policy to Increase Residential Fuel Cells and FCV Uptake

Despite the significant budget allocation described above, residential fuel cell ("Ene-Farm") and FCV uptake has been extremely poor. The government set a target of 5 million Ene-Farm units by 2030, but sales have been sluggish. Since 2017 only 40,000 to 50,000 units per year have been sold. Total sales volume as of the end of fiscal 2021 is 433,000. At this rate only around 900,000 units, or one-fifth of the target, will be sold by 2030.

Uptake for FCVs is even worse. The uptake target for 2030 was 80,000 units, but the annual sales volume since its launch in 2014 has been around 500 to 1,500 units. As of the end of fiscal 2020, the total number of units owned is a mere 5,170. Even if 1,500 units are sold per year for the next 10 years, sales would reach no more than 20,000 units by 2030. That's only one-fortieth of the target. The government's FCV strategy has clearly been a complete failure.

Promoting Ammonia Co-firing that Prolongs the Lifespan of Coal-fired Power

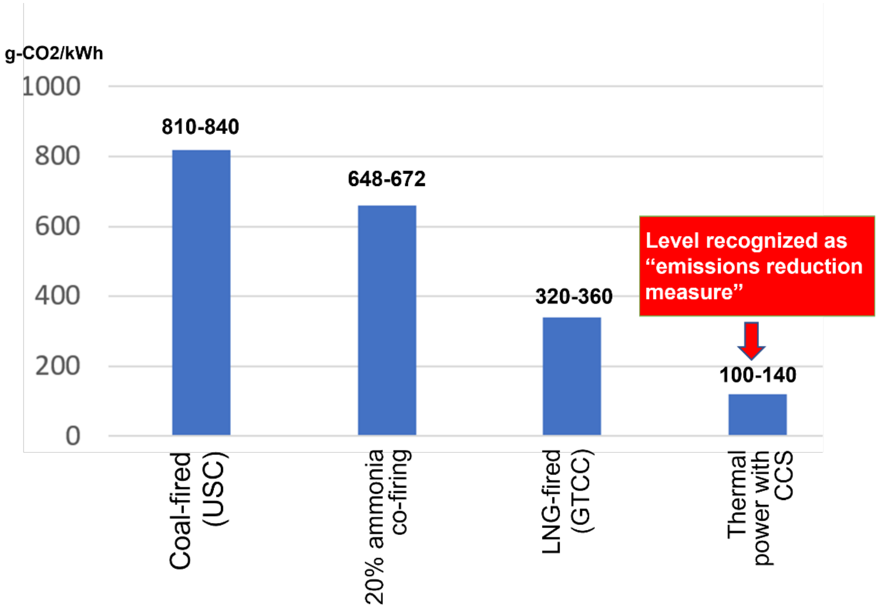
Realizing that its hydrogen strategy that focused primarily on Ene-Farm and FCVs was at a standstill, the government switched focus from hydrogen use to co-firing hydrogen and ammonia in existing thermal power plants, without clearly reviewing their failure. It projects that the hydrogen demand for 2030 will reach 3 million tonnes, but today nearly 2 million tonnes are being used in processes such as petroleum refining, meaning that demand will increase by 1 million tonnes. In the 2021 revision of the Strategic Energy Plan, hydrogen and ammonia co-firing power will account for 1% of the power supply in 2030, which will require nearly 800,000 tonnes of hydrogen. Around 200,000 tonnes will be needed if the FCV target of 800,000 units is reached, but as mentioned above only one-fortieth of that target will be achieved. In other words, most of the increase in hydrogen demand for 2030 is from hydrogen and ammonia power.

Development is moving forward on hydrogen and natural gas co-firing turbines and hydrogen single-fuel gas turbines. The first to enter production testing will be a coal and ammonia co-firing power generation, which is a key project of JERA, Japan's largest power company. JERA plans to start production testing of 20% co-firing in fiscal 2023.

Green hydrogen and green ammonia single-fuel power generation will likely play a role in the power supply system in 2050, when variable renewable energy will make up most of the power supply. In this sense, the need for developing this technology is undeniable. However, prioritizing co-firing during the process that will eventually lead to 100% single-fuel firing as a measure to reduce thermal power emissions is questionable. The biggest problem here is generating power with ammonia, which has been prioritized in co-firing with coal due to the compatibility of burning velocities.

The following graph shows that even if ammonia is 20% co-fired at ultra-supercritical coal power plants that boast the highest efficiency, emissions will be twice that of natural gas-fired power. JERA apparently plans to increase the co-firing rate to about 50% by 2030, but that would still exceed natural gas-fired power emissions. Considering that G7 leaders agreed to decarbonize all or most of their power sectors by 2035, even if a 50% ammonia co-firing is achieved by 2030, it will not be recognized as a technology that contributes to decarbonization. If anything, other developed countries will consider it to be a policy aiming to prolong the lifespan of coal-fired power which is supposed to be abolished by 2030 at the latest.

Figure 12. Comparison of Thermal Power Emission Factors



Source: Created by the Renewable Energy Institute based on the following: USC and GTCC figures are based on 2015 Environmental White Paper data. 20% co-firing represents 80% of the USC emissions coefficient. Thermal power equipped with CCS is based on the IEA's "Energy Technology Perspectives 2017."
The graph was created using median values of emission factors.

Furthermore, while ammonia does not produce CO_2 in the combustion process, it does produce CO_2 from fossil fuels in the manufacturing process. This offsets most of what is reduced in co-firing — even with the most efficient production method.[3] Whether you use green ammonia or blue ammonia combined with CCS, it will not reduce emissions even with a high co-firing rate.

Besides the emissions problem, ammonia power generation would also raise power generation costs. A report by the government-established Power Generation Cost Verification Working Group estimates that the cost of generating power by co-firing with 20% ammonia would be 20.2 JPY/1 kWh in an SDS scenario that aims for a 2˚C increase.[4]

About half of the estimated 20.2 JPY is from costs for measures against CO_2 produced in coal combustion. But according to documents by JERA, the company that is actually working to generate power from ammonia, the expenses for the equipment and gas to produce ammonia account for most of the costs, and the costs for generating power will exceed 20 JPY.[5] And as JERA's documents show, a large-scale ammonia supply chain must be established to generate power with ammonia, which currently does not exist. Such a supply chain would require a huge investment. Making a substantial financial investment in ammonia power despite it having no effect on reducing emissions is nothing short of a huge business risk.

2. Prioritization of Fossil Fuel-based Gray and Blue Hydrogen

The problem with the government's hydrogen strategy in terms of supply is that it prioritizes fossil fuel-based hydrogen instead of renewable-based green hydrogen. Until at least 2030, the main supply source in the government's strategy is gray hydrogen, which does not contribute to reducing CO_2 emissions at all. The strategy also does not clearly define standards for blue hydrogen that indicate the acceptable impact on reducing emissions to be eligible for government assistance. As mentioned in Chapter 3, the international community has been rigorously questioning how much of an impact blue hydrogen actually has on reducing emissions. At this rate, Japan risks creating a system that distributes and uses hydrogen not recognized as low- or zero-carbon energy internationally. In this case, materials and products made with Japanese hydrogen risk losing global industrial competitiveness.

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31. "Currently ammonia is manufactured by combining steam reforming with the Haber–Bosch process as a raw material for natural gas. Even with the most cutting-edge equipment, manufacturing 1 tonne of ammonia produces 1.6 tonnes of CO_2." (Source: METI Technological Assessment on R&D Projects for 2022 Budget Request [preliminary assessment]). METI has explained that achieving an ammonia co-firing rate of 20% at all coal-fired power plants owned by Japanese power giants would reduce CO_2 by about 40 million tonnes ("Fuel Ammonia Deployment Public-Private Council Interim Report," February 2021). But since manufacturing 20 million tonnes of ammonia would produce 32 million tonnes of CO_2, the net decrease from a 20% co-firing rate would be 800 tonnes, reducing emissions by only 4%.

32. Power Generation Cost Verification Working Group "Report on Power Generation Cost Verification to the Strategic Policy Committee" (September 2021)

33. At an METI committee meeting to deliberate on the clean energy strategy, JERA gave the following frank comments: "In order to deploy the new fuel of ammonia, a huge investment will be required for not only power generation and storage equipment, but also upstream fuel production equipment" and "The cost of ammonia power is about the same as other renewable power sources, so we would like to receive the same government assistance that is granted for renewable power to deploy and spread ammonia power generation." ("JERA Initiatives for Decarbonization," January 19, 2022)

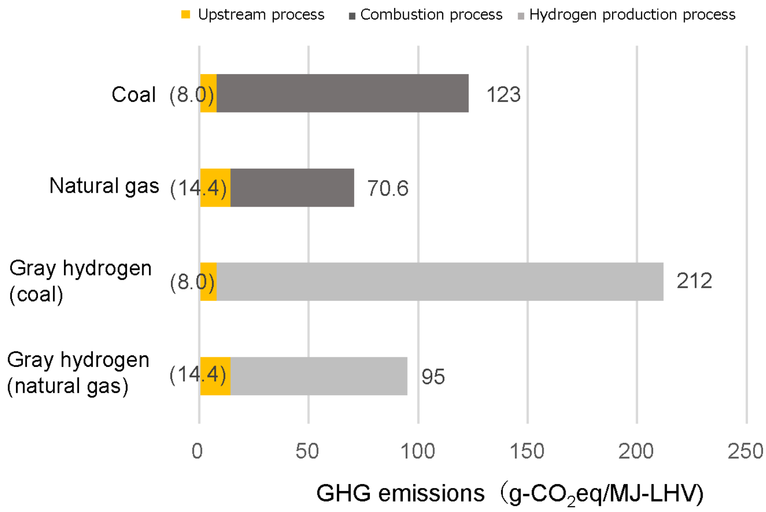
Gray Hydrogen Leads to Increased GHG Emissions

Japan's current strategy sets a hydrogen supply target for 2030 of up to 3 million tonnes per year, but the green growth strategy formulated by the government sets a target for clean hydrogen (defined as hydrogen produced from sources such as fossil fuels combined with CCUS and renewables) of over 420,000 tonnes, most of which is assumed to be gray hydrogen.[6]

Japan's supply cost target is 30 JPY/Nm³ for 2030 (336 JPY/kg, 2.8 USD/kg),[7] but this was calculated based on the assumption of importing gray hydrogen made from Australian lignite.[8]

If Japan shifts from fossil fuels to gray hydrogen, it will not contribute to reducing emissions. Not only that, gray hydrogen will actually result in more GHG emissions than fossil fuels if it is only used for fuel. Figure 13 compares GHG emissions from hydrogen, including the production process, against GHG emissions from burning fossil fuels (both per heating value). Emissions from gray hydrogen produced by natural gas reforming are 35% higher than emissions from burning natural gas. Therefore, if hydrogen is used only for fuel, such as for generating power, continuing to burn natural gas will produce less GHG emissions. The 6th Strategic Energy Plan sets a target of co-firing hydrogen at a rate of 30% at gas-fired plants by 2030, but if gray hydrogen is used, GHG emissions will be 10% higher than not co-firing.

Figure 13. GHG Emissions per Heating Value of Fossil Fuels and Hydrogen



Note: The numbers in parentheses are emissions in the upstream processes, based on median values of IEA data. Upstream processes include emissions from extracting raw materials, transportation, and methane leakage.

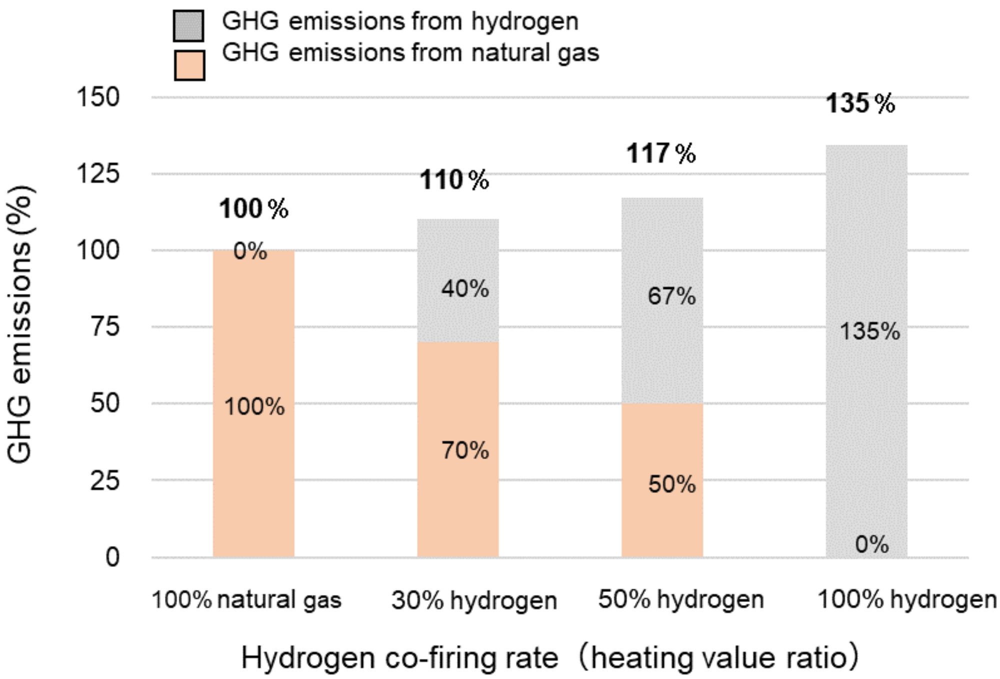
Source: Created by the Renewable Energy Institute based on the IEA's "The Role of Low-Carbon Fuels in the Clean Energy Transitions of the Power Sector" (February 2022).

34. It states that the figure of 420,000 tonnes is based on "aiming for more than the renewable-based hydrogen supply (of around 420,000 tonnes) in Germany's national hydrogen strategy released June 2020." The conditions for domestic supply are not based on a strategy aiming for the decarbonization of Japan by 2050; the figure was simply set so as to beat Germany's target. Germany has already doubled that target, however.

35. Based on an exchange rate of 1 USD to 120 JPY.

36. New import supply chain.

Figure 14. Comparison of GHG Emissions from Co-firing Gray Hydrogen with Natural Gas



Note: Based on GTCC power with a 55% power generation efficiency. Uses the same GHG emissions (LHV) as Figure 13.

Source: Created by Renewable Energy Institute based on the following data:
Heating value: "Commentary on Standard Heating Value and Carbon Emission Factor by Energy Source (FY 2018 revision)," Agency for Natural Resources and Energy (January 2020).
GHG emissions: "The Role of Low-Carbon Fuels in the Clean Energy Transitions of the Power Sector," IEA (February 2022).

Providing Assistance for Gray and Blue Hydrogen Regardless of CO_2 Emissions

Compared to the hydrogen strategies and policies of the US, China, UK, and other European countries, the biggest problem with Japan's hydrogen strategy is that the government provides assistance for gray and blue hydrogen, which have no or an unclear impact on reducing emissions respectively. The EU provides subsidies for using hydrogen to the industrial sector through a program called Carbon Contracts for Difference (CCfD). The program aims to accelerate the shift away from fossil fuels by providing assistance only to projects that use renewable-based green hydrogen and renewable energy with additionality. Germany's hydrogen strategy has focused on green hydrogen from the start. The UK and the US are also providing assistance for blue hydrogen for now, but not gray hydrogen. As mentioned in Chapter 3, these countries have established clear standards for blue hydrogen that indicate the acceptable impact on reducing emissions and only provide assistance to projects that meet those standards. And as you can see from the example of the UK which provides compensation based on the difference in cost with natural gas, the amount of compensation is lower when natural gas prices rise.

In contrast, although Japan's policy does state that "with the aim of setting some sort of threshold for CO_2 emissions, we will conduct a detailed review taking into account international circumstances and other factors," the government has not indicated when it will set standards, and aims to provide assistance "without limiting where it was manufactured or procured from" regardless of CO_2 emissions and even includes gray hydrogen.[9]

The government is also in the process of creating legislation in line with this. The Act on Rationalizing Energy Use was revised in May 2022 to incorporate facilitating the transition to non-fossil fuels. The revision defines hydrogen and ammonia as non-fossil energy sources.[38] The problem here is that the definition of non-fossil energy sources is not limited to green hydrogen and ammonia, but even includes hydrogen and ammonia made from fossil fuels.[10] At the national government council meeting held after the revision, the government stated that at the time the law goes into effect, gray hydrogen will also be treated as non-fossil energy.[11]

As mentioned above, co-firing with gray hydrogen will increase CO_2 emissions from thermal power generation. The higher the co-firing rate, the higher the emissions. Despite this, the revisions of the Act on Rationalizing Energy Use and Act on the New Energy and Industrial Technology Development Organization treat gray hydrogen as an energy source that contributes to reducing emissions as if it was green hydrogen. And if blue hydrogen is co-fired without defining emissions standards, it will be unclear how much it will actually reduce emissions. Concealing actual emissions and using inefficient coal-fired power will contribute to the continuation of coal-fired power.

This policy of using gray hydrogen and ammonia for co-firing also pervades the Long-term Decarbonized Power Source Auction METI aims to launch in fiscal 2023. At a meeting to deliberate on this theme, METI stated that it plans to make co-firing of gray hydrogen and green ammonia eligible to be included in the auction.[12]

3. Significant Lag in Domestic Green Hydrogen Production

The biggest problem the government's strategy of prioritizing fossil fuel-based hydrogen has caused is the severe delay in domestic green hydrogen production. METI has boasted that "Japan is a leading hydrogen nation," but recently it has been forced to admit that it lags behind: "Europe leads in development. Europe and other countries are also ahead in terms of the market, where renewables are inexpensive."[41] Europe and China are in the lead. And looking at the latest developments of these countries, the extent of Japan's lag is appalling.[13]

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37. "Hydrogen and Ammonia Commercial Supply Chain Assistance Program," METI (August 26, 2022)

38. The "Act on Rationalizing Energy Use" was changed to the "Act on Rationalizing Energy Use and Switching to Non-fossil Energy," and the "Act on Encouraging Energy Suppliers to Use Non-fossil Energy Sources and Facilitating Effective Use of Fossil Energy Sources" was changed to the "Act on Encouraging Energy Suppliers to Use Energy Sources in an Environmentally Friendly Way and Facilitating Effective Use of Fossil Energy Sources."

39. "Some hydrogen, ammonia, and synthetic fuels come from fossil fuels, so we will continue to deliberate on assessing this in the future, but at the time the law goes into effect, we are defining them as non-fossil fuels." Explanation by METI at the 1st 2022 meeting of the Working Group on Decision-making Standards for Plants, Energy Efficiency and Conservation Subcommittee, Committee on Energy Efficiency and Renewable Energy, Advisory Committee for Natural Resources and Energy (June 8, 2022).

40. "Securing Investments in Power Sources," METI (June 22, 2022)

41. "Domestic and International Circumstances and Current State Surrounding Hydrogen," Agency for Natural Resources and Energy, METI (June 23, 2022)

Table 2 compares the development of the two companies in Japan that lead in electrolyser development against eight leading companies in Europe and China. According to the companies' publicly available information, Japan has a production efficiency[14] of around 70%, while most European and Chinese companies have a rate of 75-80%. However, it is difficult to make an accurate comparison because for most European and Chinese companies production efficiency indicates stack efficiency, not overall system efficiency. In regard to the manufacturing capacity of electrolysers needed to deploy large quantities of hydrogen going forward, METI has repeatedly claimed that "Japan has the world's largest electrolyser in Fukushima," but European companies have already launched products in the 17-20 MW range, exceeding Fukushima's 10 MW electrolyser.

The biggest differences between Japanese companies and companies in other countries can be seen in production and delivery results, production systems, and actual and expected costs for electrolysers. Comparing companies in these areas shows that European and Chinese companies are already developing electrolysers as a business, have delivered 1,000 – 3,500 units, and are planning to build a gigawatt-level production system in the next few years. In contrast, one of the two Japanese companies is still in the demonstration stage,[15] and while the other has started deliveries, the scale is still smaller than that of companies in other countries. European and Chinese companies are building a production system with an annual capacity of several hundred megawatts to several gigawatts, while the two Japanese companies have only just started working on a mass production system.

Table 2. Main Electrolyser Companies and Development Status

	Main companies	Type	Product	Max capacity MW	Efficiency %	Results	Production capacity	Equipment cost $/kW	Target
Europe	Thyssenkrupp nucera (Germany)	Alkaline	○	20 MW	78.2*	Delivered over 600 units (10 GW)	1 GW/year		5 GW/year (2025)
	Siemens Energy (Germany)	PEM	○	17.5 MW	75	Delivered several dozen MW, received order for 50 MW			3 GW/year (2025)
	Nel (Norway)	Alkaline, PEM	○	85 MW	79.9* Alkaline	Delivered 3,500 units (since 1927)	500 MW/year	Approx. $200/kW (2025: $1.5/kg)	10 GW (2025)
	McPhy (France)	Alkaline	○	20 MW	78.2*	Received order for 100 MW unit			1 GW/year (2024)
	ITM Power (UK)	PEM	○	5 MW	70.9	Delivered 100 MW unit	1 GW/year		5 GW/year (2024)
China	PERIC	Alkaline, PEM	○	7.5 MW	81.8* Alkaline	Delivered 1,000 units (since 1984)	300 units/year	$200/kW Proposed to Sinopec	5 GW/year (2025 end)
	Longi Hydrogen	Alkaline	○	7.5 MW	79.9*		1.5 GW (2022 end)	$205/kW Proposed to Sinopec	
	Cokerill Jingli (John Cokerill)	Alkaline	○	6.5 MW	70.3	Delivered 1,000 units (500 MW)	200 MW/year (2021)	$205/kW Proposed to Sinopec	Planning Gigafactory in France
Japan	Asahi Kasei	Alkaline	–	10 MW	70.3	Participated in demonstration project in Germany		$1,200/kW (2022)	$433/kW 2030 Target
	Hitachi Zosen	PEM	○	1 MW	70.3	Delivered several dozen units, received orders for 15 MW		$3,158/kW (2022)	$542/kW 2030 Target

Note: Efficiency is based on higher heating value (HHV). *Stack efficiency

Source: Costs for Chinese companies are based on "Update on Sinopec's Green Hydrogen Project," BloombergNEF (May 2022). The rest of the contents were created by the Renewable Energy Institute based on companies' publicly available information (see References 4 at the end of this report).

42. Ratio of 1 Nm^3 to power required to produce 3.517 kWh-HHV of hydrogen.

43. "Asahi Kasei to Commercialize World's Largest Hydrogen Production System by 2025," The Nikkei (November 24, 2022)

Delay in moving to mass production inevitably leads to a difference in costs. The equipment cost of electrolysers is 144,000 JPY/kW (1,200 USD/kW)[16] for the Japanese company using alkaline electrolysers in the demonstration stage, and 200 – 205 USD/kW for the three Chinese companies (electrolysers to go online in 2023). In Europe, Norway's Nel is aiming to attain hydrogen costs of 1.5 USD/kg-H2 by 2025. Based on the company's estimate of expected power costs (20 USD/MWh), electrolyser costs can be projected to be under 200 USD/kW. Japan's targets for 2030 is 52,000 JPY/kW (433 USD/kW) for alkaline electrolysers and 65,000 JPY/kW (542 USD/kW) for PEM electrolysers, so Chinese manufacturers will soon attain about half the costs of Japan's target for 10 years from now.[17]

Japan's Estimation of Green Hydrogen Costs in 2030

Green hydrogen production costs are impacted by both equipment costs for electrolysers and renewable power costs. It is well known that Japan's renewable energy costs, including solar and wind, are markedly higher than other countries.

Figure 15 indicates estimates of green hydrogen costs based on renewable power and electrolyser costs. Based on the electrolyser cost targets for 2030 (52,000 JPY/kW or 433 USD/kW for Alkaline) and solar PV costs for 2025 set by the Procurement Price Calculation Committee, the price of hydrogen manufactured in Japan in 2030 is estimated to be 4.51 USD/kg (48.4 JPY/Nm^3). This is 1.6 times the government's target price of 30 JPY/Nm^3 for 2030.

But this target of 30 JPY/Nm^3 for 2030 was calculated based on the target price of hydrogen in the event brown hydrogen is imported from Australia — in other words, it is the target price for importing gray hydrogen. According to a review carried out by IEA and BNEF on importing blue and green hydrogen produced in Australia, after adding other import-related costs, such as conversion and transportation to hydrogen carriers for storage and transport, the total comes to nearly the same as the above-mentioned estimated costs for domestic production.[18]

Figure 15 shows that the key to lowering costs further is electrolyser costs and renewable power costs. In order to be on par with the European and Chinese companies mentioned above, Japan needs to scale up equipment and pursue ways to lower renewable power costs further, including surplus power.

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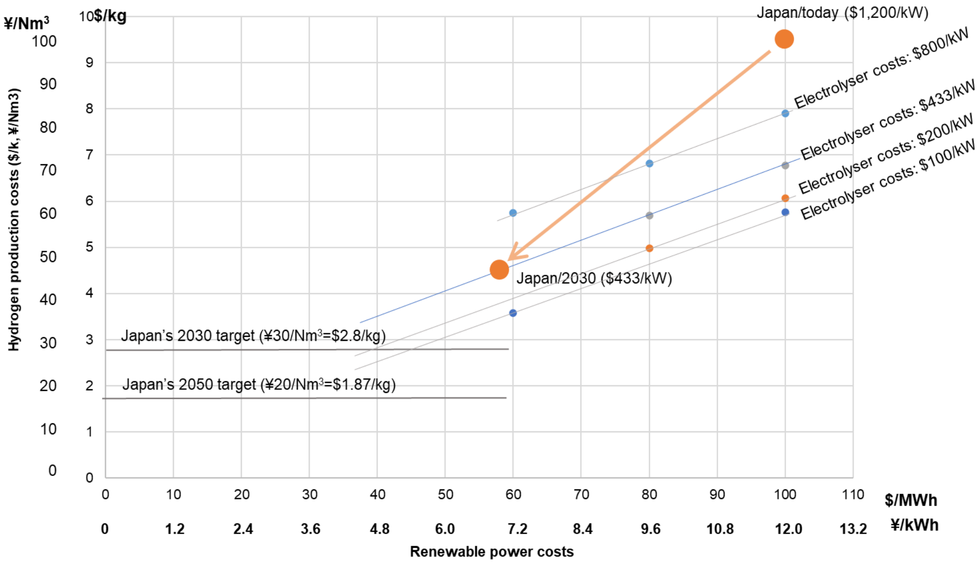
44. R&D and Social Implementation Plan for "Hydrogen Production through Water Electrolysis Using Power from Renewables" project, METI (May 2021)

45. Based on an exchange rate of 1 USD to 120 JPY.

46. "The Role of Low-Carbon Fuels in the Clean Energy Transitions of the Power Sector," IEA (October 2021) and "Japan's Hydrogen Dreams Are Falling Behind Europe," BloombergNEF (October 2020)

Figure 15. Estimation of Hydrogen Production Costs Based on Power and Electrolyser Costs



Note: Electrolyser costs in Figure 15 are based on the R&D and Social Implementation Plan for "Hydrogen Production through Water Electrolysis Using Power from Renewables" project, METI (May 2021). Based on an exchange rate of 1 USD to 120 JPY.

Renewable power costs for 2030 are based on fiscal 2025 solar PV costs in "Opinions on Procurement Prices for FY 2022 and Onward," Procurement Price Calculation Committee (April 2022).

Source: Renewable Energy Institute

4. Argument for Rebuilding the Hydrogen Strategy

As pointed out above, the initial practical goal of Japan's hydrogen strategy aimed to expand the use of residential fuel cells and fuel cell vehicles that Japanese companies had developed and commercialized ahead of other countries. However, the vision laid out in the strategy was to achieve a "hydrogen society where hydrogen is used universally," a vague concept with no clearly defined purpose for using hydrogen.

Since the strategy is not part of a decarbonization strategy, its focus has been on use in applications that are low priority in terms of decarbonization, and policy has aimed at importing fossil fuels that contribute little or nothing to reducing emissions and building a supply chain to support it. As a result, five years after the Basic Hydrogen Strategy was formulated, Japan faces the reality that it lags behind in producing green hydrogen and in creating emissions standards for blue hydrogen, contradicting its message that it will lead the world in hydrogen. The strategy's main focus from the beginning has been on increasing uptake of residential fuel cells and fuel cell vehicles, but actual uptake has been far below the target and the many hydrogen stations built across the country are suffering from sluggish business.

Japan's hydrogen strategy must be rebuilt as part of a decarbonized energy strategy. This section will present points of argument for rebuilding Japan's hydrogen strategy based on the above analysis.

Point 1. Re-examine the role of hydrogen in the decarbonization of Japan and minimize the amount needed.

The priority in re-examination of the strategy should be to identify how much hydrogen is needed and what areas it is needed in to achieve the decarbonization of Japan. Japan's Green Growth Strategy formulated in December 2020 states that a supply of around 20 million tonnes will be needed for 2050. The strategy does not clearly articulate the grounds for this figure and breaks down "potential domestic hydrogen demand (deployment quantity-based hypothesis)" into the following three areas.

- Hydrogen power: Around 5-10 million tonnes/year
- Hydrogen basedsteelmaking: Around 7 million tonnes/year
- Transportation (e.g. commercial vehicles): Around 6 million tonnes/year

These three applications differ from the government's initial focus on residential fuel cells and fuel cell vehicles. They are usable applications that do not fall under Agora's category of "bad ideas."

In the area of power generation, the government aims to have hydrogen and ammonia make up 10% of the energy mix by 2050. Even if hydrogen made up all of the energy mix, it would require around 6 million tonnes of hydrogen. Green hydrogen power (or green ammonia power) may be needed as a means of ensuring flexibility in order to build a power supply system based on 100% renewables. However, as pointed out in Chapter 1, this can be accomplished with other means, such as inter-regional power grids, battery storage and pumped hydro power, and demand management. Whether hydrogen power is needed in the future, and if so how much, must be discussed as part of deliberations on decarbonizing Japan's power system.

Hydrogen based steelmaking is deemed as a "no-regret" application in international discussions. Today Japan produces 80 million tonnes of crude steel. It is true that switching that entire amount to hydrogen based steelmaking would require around 7 million tonnes of hydrogen per year. However, to transition to a sustainable industrial system, Japan must both achieve decarbonization and switch to a circular economy. From this perspective, Japan should consider transitioning to steel recycling on a large scale.[19] It is hardly a valid assumption to expect that the volume of crude steel production will be the same in 2050 as it is now.[20]

Furthermore, practical application of electric vehicle technology has progressed in both compact and heavy duty trucks. They have already started to enter the market in Europe, the US, and China. METI has estimated that around 6 million tonnes of hydrogen will be required if approximately 2.1 million compact and heavy duty trucks are converted to fuel cell trucks.[21] Considering trends in electric vehicle development, this estimate is far too high.

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47. Actually, Japanese manufacturing giants like Nippon Steel and JFE have reported that they are considering transitioning to electric furnaces. Example: "JFE to Switch from Blast to Electric Furnaces by 2028, Reducing CO2 Emissions," The Nikkei (August 26, 2022)

48. In addition, there is also the problem of whether hydrogen based steelmaking will be economically profitable in Japan. The Japan Iron and Steel Federation requires hydrogen prices to be 8 JPY/Nm^3, which is about one-third of the government's cost target for 2050. While renewable power costs will undoubtably decrease by 2050 in Japan, it is unlikely that it will decrease enough to reach the level of 8 JPY/Nm^3.

49. "Interim Report on Challenges and Measures for Future Hydrogen Policy (Proposal)," METI (March 22, 2021)

Besides these three areas, hydrogen demand may also exist in other industrial applications, long-distance air travel, and marine transportation. Documents of the committee established by METI to deliberate on the commercial supply chain[22] indicate “potential demand” in different areas, such as around 6.95 million tonnes for the chemical industry and 34 million tonnes for heat demand. When combining this with the three areas above, total demand would exceed 60 million tonnes. But this estimate is based on unrealistic assumptions such as meeting the entire amount of current heat demand with hydrogen or replacing all heavy oil in existing coastal vessels with hydrogen.

Discarding the fantasy of a “hydrogen society where hydrogen is universally used in everyday life and industrial activities” and comparing the strategy with other decarbonization measures, the crucial point of how much hydrogen will be needed to decarbonize Japan is completely unclear. The government’s target of 20 million tonnes has no rational grounds. To rebuild the hydrogen strategy, we must define how much hydrogen will be needed and where it will be needed to decarbonize Japan by comparing it with other means of decarbonization and premising the strategy on electrifying energy demand, facilitating a circular economy, and improving energy efficiency.

As indicated in this report, the price of green hydrogen supplied in Japan is unfortunately very likely to be more expensive than in other countries in terms of both domestic production and importing in the future. If this is the case, in order to decarbonize the country, Japan should step up efforts in electrification and transition to a circular economy and minimize hydrogen use.

Point 2. Build a supply system that combines importing and domestic production with a focus on green hydrogen.

The second point we need in our government hydrogen strategy is to focus on the use and supply of green hydrogen, which clearly contributes to decarbonization. The biggest flaw in Japan’s hydrogen strategy is that it aims to expand the use of anything with the word “hydrogen” in it, even gray hydrogen. The policy of providing assistance for using gray hydrogen, which increases GHG emissions if burned, should be rectified immediately.

Green hydrogen could be supplied by both importing from other countries and producing it domestically. Renewable energy prices in Japan are expected to fall dramatically by 2030 and 2050, but countries like Australia and those in the Middle East that can build large-scale solar PV systems thanks to more hours of sunshine can achieve Solar PV costs far less than that of Japan. Green hydrogen production costs will be lower in these countries than Japan, but considering the additional costs of transportation mentioned above, importing hydrogen from them may end up costing the same as producing it in Japan.

Besides costs, there are two other reasons why building a domestic supply chain for green hydrogen is important. The first is energy security. So far Japan has relied on imported fossil fuels for most of its energy supply. Even according to the calculations of the government, which considers nuclear power domestic energy, Japan’s energy self-sufficiency rate is only 12%. Japan would be able to greatly increase its energy self-sufficiency rate if it supplied most of its power with renewable energy, eliminated fossil fuel power, and met demand for energy in areas where electrification is not possible with domestically produced green

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50. “Hydrogen and Ammonia Commercial Supply Chain Assistance Program,” METI (August 26, 2022)

hydrogen. In March 2021 Renewable Energy Institute released "Renewable Pathways: The Strategies to 100% RE for a Carbon-neutral Japan." The strategy proposes to import all green synthetic fuel used for transportation and enough green hydrogen to meet half the demand for green hydrogen,and produce the remaining half domestically. This would result in an energy self-sufficiency rate of 68% for Japan.

This point is important because producing green hydrogen while taking measures such as enhancing the inter-regional connection of power grids, using battery storage, and conducting demand management could play a key role as flexible demand in order to create a stable power supply and compensate for changes in a power system that is largely covered by variable renewable energy such as solar and wind.

As pointed out at the beginning of this chapter, the fact that Japan's hydrogen strategy has not focused on green hydrogen is a reflection of downplaying the role of renewable energy in the power supply. Presently renewable energy makes up just 20% of the power supply — that's only about half of the level of Europe. Japan's 2030 target for renewables is only 36-38%. The EU's REPowerEU plan released in May 2022 increases the renewable energy target for 2030 and clearly states that 69% of its power supply will be from renewables. Germany, which is particularly ambitious in green hydrogen development, has set a renewable power target for 2030 of 80%.

In order to have an accurate discussion of an ideal green hydrogen production system, Japan must develop a location strategy for domestic renewable power — particularly on- and offshore wind power, consider a plan for the regional distribution of power demand and improving power grids, and consider the optimal size and location for hydrogen production. These issues must be discussed on the national government level. And the discussion must be premised on greatly enhancing renewable power targets and striving to build power system to achieve it.

Point 3. Re-examine Policies Premised on Gray and Blue Hydrogen

The third point needed to rebuild the strategy is to re-examine existing policies that promote the use and expansion of gray and blue hydrogen. Specifically, there is a pressing need to re-examine the following:

(1) LCA-based GHG emissions standards and treatment of hydrogen in Japanese law

As mentioned in Chapter 3, rigorous emissions standards are being set internationally for blue hydrogen. METI has put off setting emissions standards for hydrogen it is facilitating the use of, but in order for the decarbonization performance of materials and products distributed in Japan's hydrogen supply chain to be recognized internationally, it must set LCA-based GHG emissions standards.

The policy of treating even gray hydrogen as something that contributes to reducing emissions laid out in the Act on Rationalizing Energy Use that were revised in 2022 should be changed immediately. As indicated above, gray hydrogen produces more GHGs than the fossil fuels used to make it if you include the manufacturing process. Therefore, thermal power that uses gray hydrogen will produce more GHGs than conventional thermal power, and products manufactured using this power will be considered to have a low decarbonization performance internationally.

Steel production is a field that will likely see a significant demand for hydrogen, and needs for zero-emission "green steel" have already begun to emerge on the demand side.[23] Even steel made with the hydrogen reduction method will not be considered emission-free if it is made with gray hydrogen. It goes without saying that cars with bodies made from gray steel will be considered to have low decarbonization performance.

Even if the government makes national rules that recognize gray hydrogen as contributing to decarbonization, international assessments will be different. Companies will have to release data under two separate standards and risk being seen as greenwashing.

(2) Policy to build a large-scale supply chain

The government is working to build a large-scale supply chain that focuses on gray and blue hydrogen even though they have no or an unclear impact on reducing emissions and it has yet to define how much hydrogen will be needed and what it will be needed for in 2030 and 2050.

Building a large-scale supply chain seems to be the crux of METI's hydrogen policies. For example, documents from the first meeting of the Hydrogen Policy Subcommittee, a new subcommittee established in March 2022, state, "In order to continue to lead the world in the fields of hydrogen and ammonia, contribute to global decarbonization, and penetrate growth markets worldwide, we need to build a commercial supply chain for hydrogen and ammonia ahead of other countries and expand its implementation."

It is true that a certain amount of green hydrogen will likely be used in applications that are really necessary in 2050, so a supply chain itself needs to be built. The purpose of building a supply chain should be to efficiently supply hydrogen to meet the determined volume of demand in the areas of demand., However, METI's strategy appears to make the development of the supply chain itself a self-objective. The rationalization given for building a supply chain is backwards logic: it assumes there will be a big demand for hydrogen anyway, so any hydrogen can be used to create a big hydrogen demand even if it is gray.

METI's strategy of starting from building a supply chain poses huge risks. One risk is pouring public funds into fields where the need is low. This risk has already become a reality in one area, that of hydrogen stations, which were built under the assumption that FCV uptake would increase. As of May 2022, 161 hydrogen stations have been built across Japan. By prefecture, Aichi has the highest concentration of stations. According to planning documents, the required number and distribution of stations is based on an unreasonably high uptake target and assumes the stations would mainly be used by passenger automobiles.[24] More than a few of the hydrogen stations around the country were built with the assumption that only passenger automobiles would use them. It is highly questionable that it was reasonable to invest in hydrogen stations with mainly passenger automobiles in mind even though no increase in FCV uptake is expected.

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51. For example, the Climate Group, the NPO leading the RE100 initiative, has launched a project called "SteelZero."

52. "Aichi Prefecture Hydrogen Station Development and Distribution Plan" (accessed August 31, 2022) https://www.pref.aichi.jp/site/suiso-fcv/suiso-st-plan.html

The utilization rate of hydrogen stations has been sluggish, and large amounts of public subsidies have been needed to cover both installation and operational costs. According to documents released by METI, 2.53 billion JPY in subsidies have been granted to cover operational costs in fiscal 2020. This suggests that about 20 million JPY per station, or nearly half of total operational costs, is paid for with public subsidies.[25]

The premise of METI's strategy is dubious in terms of both the approach to the supply chain and the source of hydrogen. As indicated in this report, in the 2020s the price of green hydrogen in many countries continues to become cheaper than blue hydrogen. In order to build an optimal supply chain for 2030 and beyond, a supply source of green hydrogen must be included in the scope. Japan will likely be able to import a portion of green hydrogen from other countries in the future, so building import centers is fairly reasonable, but deliberations on building a domestic supply chain must also include establishing domestic green hydrogen production centers.

The strategy of creating a large hydrogen demand to build a large-scale supply chain and using even gray hydrogen to do it is a huge risk. And as mentioned above, it also poses a reputational risk for the hydrogen used by Japan and the products using that hydrogen. If word spread that Japan's hydrogen supply chain distributes gray hydrogen and blue hydrogen with no emissions standards, Japanese companies would be at a disadvantage in the international market where decarbonization performance is a concern.

METI's hydrogen strategy emphasizes industrial policy over decarbonization policy. Since decarbonization is a basic rule of the new socio-economy, it is right to drive decarbonization policy in combination with industrial policy. However, the government should keep in mind that a policy that promotes gray hydrogen which is at odds with decarbonization will never succeed even as an industrial policy.

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53. "Current State of FCVs and Hydrogen Stations," METI (March 18, 2021)

Conclusion

Led by the developed countries of Europe and the US, global energy policy has undergone dramatic changes in the last 20 years since around the year 2000. These changes have accelerated since the Paris Agreement was adopted in 2015 to transition to a decarbonized society. And with the energy crisis brought about by the Russian invasion of Ukraine this year, momentum has grown even further to accelerate independence from fossil fuels. Energy transformation is progressing not only in the developed countries of Europe and the US, but also in emerging countries such as China and India, and other countries in the Middle East and South America. This year change has begun even in Australia, which had previously prioritized fossil fuels.

Having experienced the Fukushima nuclear disaster in 2011 and been forced to depend on fossil fuels from other countries for many years, Japan should be leveraging the trend of transitioning to renewable energy and playing the role of a world leader in decarbonization and independence from fossil fuels. But instead, it has clung to policies that maintain the old energy supply system.

The results of Japan's policies are plain to see when comparing its energy mix with other countries. In the last 20 years, its fellow industrial nation of Germany and fellow island nation of the UK have increased the amount of renewable energy in their power supply by over 40 percentage points — from under 5% to over 40%. In contrast, Japan has only increased renewable energy by only 10 percentage points — from 10% to 20%.

Despite the fact that solar PV technology was developed in Japan, today its domestic supply system is inferior to that of other countries. Japanese companies were also among the first to enter the wind power business, but the growth potential was lost due to the old-fashioned power system.

Even today there are those in the government who do not understand the huge potential of renewable energy in Japan and stubbornly cling to fossil fuels and nuclear power. This is supported by the actions of some companies who are trying to protect their narrow vested interests.

If Japan does not fundamentally revise its hydrogen strategy, the hydrogen business in Japan may lose its growth potential just like solar and wind did. Japan must place its hydrogen strategy in its decarbonization strategy and rectify the idea that any type of hydrogen will do. Unless the country quickly establishes GHG emission standards for blue hydrogen that are internationally recognized, the international supply chain it is focusing efforts on will not earn trust. The government also needs to define what applications are truly needed to achieve decarbonization, and build a system to meet demand by supplying domestically produced hydrogen and partially supplementing that with imports in accordance with how fast renewable energy grows.

If Japan changes its strategy and policies, it will be able to play an important role in the global green hydrogen business by leveraging Japanese companies' experience gained from efforts in building a supply chain. But time is running out.

Re-examining Japan's Hydrogen Strategy

Moving Beyond the "Hydrogen Society" Fantasy

September 2022

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