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Hydrogen and ammonia co-firing in the power sector:

Japan is choosing to expand fossil-fuel extraction and perpetuate coal and LNG

Contents

Executive Summary

The government of Japan has declared a goal of carbon neutrality, but it is attempting to maintain the current system of thermal power generation through policies to use hydrogen and ammonia as fuel. Meanwhile, electric power companies, power plant manufacturers and major trading companies are trying to expand their businesses with the help of massive government subsidies. However, as things are currently progressing , most of these initiatives are based on producing ammonia and hydrogen from fossil fuels, including natural gas from Southeast Asia, North America, and Russia, and brown coal (low quality coal) from Australia. In reality, these are new fossil fuel development projects. To limit global warming to 1.5°C under the Paris Agreement, developed countries are being called upon to phase out coal from their power sectors by 2030 and to decarbonize them by 2035. In that context, the use of hydrogen and ammonia in power generation poses the following problems:

- There is anticipation that carbon capture, utilization and storage (CCUS) technologies will reduce CO_2 emissions from the production of ammonia and hydrogen from fossil fuels, but until they become commercially viable CO_2 will be emitted, and many challenges still remain.
- Even if 20% co-firing with ammonia or hydrogen becomes viable by 2030, the fuel uses of coal and LNG will continue, which means the continuation of massive CO_2 emissions. Halving greenhouse gas emissions is needed by 2030, but these technologies can make little contribution to emission cuts, so this strategy is inconsistent with the 1.5°C goal of the Paris Agreement.
- Ammonia and hydrogen-related technologies and the associated CCUS come with very high costs, so the value of these technologies will decline as decarbonization gains momentum and the cost of renewable energy drops further. These technologies are not compatible with emission reduction strategies and exacerbate the risk that investments will become stranded assets.

Promoting the use of hydrogen and ammonia from fossil fuels for electric power generation in the absence of evidence that they will promote decarbonization is not consistent with the significant decarbonization developed countries must achieve by 2030. In fact, the intent of these schemes appears to be to protect the profits of certain companies and to throw a lifeline to coal and LNG.

Technologies that utilize hydrogen or ammonia are not valid options in any strategy to decarbonize the thermal power sector, and there is no assurance that they will help Japan achieve CO_2 emission reductions that would be consistent with the 1.5°C goal. The government and industry should put the priority on completely phasing out coal power by 2030 and working to fulfill obligations to help limit warming to 1.5°C by promoting decarbonization.

Introduction

Thermal power generation using coal and liquefied natural gas (LNG) account for over one-third of Japan's carbon dioxide (CO_2) emissions, making this sector the largest source of emissions and the most important sector in terms of achieving net zero greenhouse gas (GHG) emissions by 2050. In October 2020, the Japanese government announced a policy of aiming to be carbon neutral by 2050. It then came out quickly with policies to utilize hydrogen and ammonia as fuels for the thermal power sector. Huge sums of official financial support and corporate investment are now being mobilized to this end. Government and industry both refer to hydrogen and ammonia as "decarbonized fuels" with the aim of achieving "decarbonized thermal power generation." But we must ask, is it really possible to have both decarbonization, which means emitting no CO_2, and thermal power generation, which means the combustion of fossil fuels?

This paper examines the related actions of government and industry and the possible CO_2 emission reductions from using hydrogen and ammonia as fuels in the thermal power sector, and also discusses costs and environmental impacts. We find that power generation using hydrogen and ammonia will induce new fossil fuel development and prolong the life of thermal power generation. We also reveal that they pose major problems in terms of promoting climate action, transforming Japan's industrial structure, and fostering new industries.

1. Government and industry initiatives

(1) The policy of hydrogen and ammonia co-firing in thermal power generation

(a) Origins of the policies

After then-Prime Minister Yoshihide Suga declared Japan would be carbon neutral by 2050 in his policy speech to the Diet (parliament) on October 26, 2020, the government rapidly accelerated efforts for the use of hydrogen and ammonia as fuel in thermal power generation. Research had already been underway regarding the use of hydrogen, through industry-academia-government discussions by the Hydrogen and Fuel Cell Strategy Council, launched in December 2013, and its "Basic Hydrogen Strategy" was released in 2017[1]. Up to that point, the emphasis had been on aspects such as developing the international hydrogen supply chain and the use of fuel cells for mobility, while only one page of the report was dedicated to uses in the power sector. Discussions originally started with the use of hydrogen for power generation being considered as a fuel to replace LNG, but it is now being promoted together with coal for power generation. Coal power can involve a process in a coal gasification furnace, which uses carbon monoxide and hydrogen to generate coal gas. This is the same as Integrated Coal Gasification Combined Cycle (IGCC) technology being promoted in a project by the Osaki CoolGen Corporation to increase the efficiency of

1 Cabinet Decision on renewable energy and hydrogen, "Basic Hydrogen Strategy," in Japanese, December 2017.

coal-fired power generation. There appears to be an effort to avoid use of the term IGCC in order to present this as a new decarbonization technology and focus attention on the use of hydrogen.

Meanwhile, the use of ammonia for co-firing with coal had only been done on a small scale, but after the government's carbon neutral declaration, new activities surfaced at a rapid pace. Industry is familiar with the handling of ammonia through the extensive use of ammonia as feedstock in fertilizers and chemical products, and since it has high hydrogen density, it has also attracted attention as a hydrogen energy carrier enabling the efficient transport and storage of hydrogen energy.

Just one day after the Prime Minister's carbon neutral declaration, the Agency for Natural Resources and Energy established the Public-Private Fuel Ammonia Promotion Council on October 27, 2020[2], and started discussions on technical and economic issues for introducing and expanding the use of ammonia as a fuel, with government and industry progressing on a shared timeline to address the issues (Column 1). The Interim Report[3] released in February 2021 presented a roadmap for the introduction of fuel ammonia, projecting Japan's annual ammonia imports at 3 million tons in 2030 and 30 million tons in 2050. Japan is currently using about 1 million tons of ammonia per year mainly as urea resin and in fertilizers, of which about 800,000 tons are from domestic production and 200,000 tons from imports. Based on the potential direct use of ammonia as fuel, the interim report projects massive imports of ammonia for use in coal-fired power generation and shipping, sets the stage to rush ahead with ammonia production and importation on a scale that would exceed the current global trade volume of about 20 million tons, and builds a framework to promote that scenario.

Column 1 : Was Japan's shift toward fuel ammonia decided mainly to help vested interests?

Based on the date of the launch of the Public-Private Fuel Ammonia Promotion Council, just one day after the government's carbon neutral declaration, it would appear as if the timing was coordinated. Member companies in the Council include IHI, JERA, J-POWER, JGC Holdings (Japan Gasoline Company), Marubeni Corporation, Mitsubishi Heavy Industries, and Mitsubishi Corporation, and in one way or another they are all involved in fuel ammonia-related projects and receiving government subsidies[4]. In effect, they all have vested interests. The council includes the Ministry of Economy, Trade and Industry (METI), plus the Japan Bank for International Cooperation (JBIC), and Nippon Export and Investment Insurance (NEXI), and most of its meetings and materials are not made public. Only meeting topics are announced, and the interim report was drafted and released through a process that lacked objectivity and transparency. Crucial technology choices relating to decarbonization for Japan may have been decided with the implicit aim of supporting member companies, as the council mainly includes actors who have vested interests.

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2 Ministry of Economy, Trade and Industry (METI) "Guidelines for Establishment of Public-Private Fuel Ammonia Promotion Council," in Japanese, October 2020.

3 METI, "Public-Private Fuel Ammonia Promotion Council, Interim Report," in Japanese, February 2021.

4 METI, "Member List of the Public-Private Fuel Ammonia Promotion Council," in Japanese, February 2021.

(b) Role in Japan's Green Growth Strategy

The government's Green Growth Strategy Through Achieving Carbon Neutrality in 2050 (updated version), released in June 2021 states that "decarbonization of the power sector is the major premise for achieving carbon neutrality in 2050," but goes on to say "regarding thermal power, the government will pursue its use as an option, presupposing recovery of CO_2."[5] It is surprising that the intention is not to reduce the use of thermal power, but rather, to pursue it. On top of that, the strategy document is sprinkled with policies for technology development, transportation, ports and harbors, and market development, including tax measures and government subsidies to support commercialization and cost reductions of ammonia and hydrogen-powered electricity generation.

The strategy places high expectations on hydrogen power generation as "one of the options of power source in the era of Carbon Neutrality, which may also contribute to stabilization of system as a balancing capacity," also stating that "a full launch of the domestic hydrogen market by creating a large demand in the electric power generation field will be supported," and looks at "export not only to the developed countries where projects are going ahead, but also to Asia with vigorous growth of electric power demand".

The strategy presents ammonia power generation as a decarbonized fuel and as a key to the transition to a hydrogen society, through co-firing with coal, and aims to introduce and promote 20% ammonia co-firing with coal thermal in the short term to 2030, increasing to a 50% mix in the longer term to 2050, proactively promoting technology development to bring that to 100%. Through this, it is aiming for practical application by replacing existing thermal power generation, and it has the intention to spread this technology worldwide.

(c) Japan's Sixth Strategic Energy Plan

The "Sixth Strategic Energy Plan" decided in October 2021[6], states that since it is "difficult to supply all 100% of electricity demand with one type of energy source" it is "necessary to pursue new options that require innovation such as thermal power premised on hydrogen- and ammonia-fired power generation and carbon storage and use through carbon capture, utilization and storage (CCUS)." Based on that, it says that this is "one effective option in terms of promoting decarbonization of electricity sources, since much of the existing power generation equipment such as gas turbines, boilers, desulfurization equipment can still be used as-is," and promotes overcom-

5 After its initial release on December 25, 2020, a more detailed version was released on June 18, 2021 by the Cabinet Secretariat, Ministry of Economy, Trade and Industry, Cabinet Office, Financial Services Agency, Ministry of Internal Affairs and Communications, Ministry of Foreign Affairs, Ministry of Education, Culture, Sports, Science and Technology, Ministry of Agriculture, Forestry and Fisheries, Ministry of Land, Infrastructure, Transport and Tourism, and Ministry of the Environment. The Ministry of Economy, Trade and Industry led the formulation of the strategy.

6 METI, Sixth Strategic Energy Plan," to be posted here, October, 2021.

ing technical issues so that power generation from hydrogen and ammonia can function as major suppliers and stabilizers of the electrical power system in 2050. By 2030, it envisions introducing and promoting 30% hydrogen co-firing with gas thermal, 100% hydrogen firing, and 20% ammonia co-firing with coal thermal, so that in the fiscal year 2030, hydrogen and ammonia account for about 1% of the electricity mix. As for CCUS and carbon recycling, premised upon the commercialization of CO_2 capture and storage (CCS), it promotes the development of suitable sites, technical development, transportation demonstrations, and preparation of the business conditions required for introduction by 2030, and says that CO_2 emissions from thermal power generation will be reduced.

(2) Policy directions

(a) Assistance through subsidies

The public funds are already flowing. Subsidies are already flooding into a variety of R&D and demonstration projects, particularly for hydrogen. The "CO_2-free Hydrogen Energy Supply-chain Technology Research Association (HySTRA)"[7] was established in 2016 to create a hydrogen supply chain, including hydrogen production from brown coal, as well as hydrogen transportation, storage and utilization, with the aim of commercialization by around 2030. Its various projects include the Demonstration Project for Establishment of Mass Hydrogen Marine Transportation Supply Chain Derived from Unused Brown Coal. (Brown coal is low-grade coal that is not generally used in coal-fired power generation due to high moisture content, impurities and low calorific value). HySTAR member J-POWER has received subsidies from Japan's New Energy and Industrial Technology Development Organization (NEDO) and the Australian government to build a demonstration facility to produce hydrogen through brown coal gasification in the Latrobe Valley (Victoria State) in Australia[8].

Also, for the move to carbon neutrality in 2050, the government decided to establish the two trillion yen (about US$17.5 billion) Green Innovation Fund at NEDO and continue with ten years of funding for companies for R&D, demonstration, and social implementation[9]. This is a large money subsidy system for large projects budgeted at 20 billion yen or more (about US$175 million) in total project costs (government portion only). This includes projects such as the "Development of Technologies for Carbon Recycling and Next-Generation Thermal Power Generation / Research, Development and Demonstration of Technologies for Ammonia Co-Firing Thermal Power Generation" program for projects having a total budget of under 10 billion yen (about US$88 million) over five years to 2025, and combined contracts and/or subsidies under 20 billion yen (about US$175 million) over five years. A call for proposals was made, and two of Japan's top ther-

7 The seven members include J-POWER, Iwatani Corporation, Kawasaki Heavy Industries, Shell Japan Limited, Marubeni Corporation, ENEOS Corporation, and Kawasaki Kisen Kaisha ("K" Line).

8 J-POWER, "Hydrogen production started at coal gasification and hydrogen refining facility," February 2021.

9 METI, "Basic Policies for the Project for the Green Innovation Fund," in Japanese, March 2021.

mal power companies J-POWER and JERA applied and are receiving this funding.

(b) JOGMEC as a key player

The Japan Oil, Gas and Metals National Corporation (JOGMEC) was established in 2004 based on the JOGMEC Act, from the integration of its predecessors, the Japan National Oil Corporation and the Metal Mining Agency of Japan. Its capacity to acquire international resources has been bolstered through restructuring three times for the purpose of securing oil supplies, etc. The JOGMEC Act amended in 2020 states that if it is difficult for the private sector to procure fuel for power generation in an emergency, JOGMEC can procure it based on the Electricity Business Act at the request of the Minister of Economy, Trade and Industry. If it becomes difficult to procure fuel for power generation due to the divestment (withdrawal of fossil fuel investments) that has been occurring in recent years, the Minister can request JOGMEC to intervene and procure fuel. In other words, a framework has been created that allows JOGMEC to procure fuel with the sanction and financial assistance of the national government even when the private sector withdraws due to the wave of decarbonization.

One can see signs of JOGMEC's omnipresence in subsidy programs for hydrogen and ammonia power generation. We examine some of them in specific projects described below.

(c) Regulatory loopholes promote ammonia and hydrogen for inefficient coal power

In July 2020, then-Minister of Economy, Trade and Industry Hiroshi Kajiyama directed his ministry to consider concrete measures such as "new regulatory measures to ensure the fade-out of inefficient coal toward 2030" and "the establishment of mechanisms to induce the early exit of inefficient coal while still securing the required supply capacity for a stable supply." With that, the government at last started to move on measures to curb the use of existing coal power. An April 2021 interim report set a new target for coal power generation efficiency at least 43% for each operator, regardless of the power generation technology being used[10]. In the global momentum to curb the use of coal power and phase out coal, it is a problem that the government response is just to increase power generation efficiency. However, it is further problematic that it allows not only the use of biomass fuel co-firing and by-product gas without considering life cycle CO_2 emissions, but also to calculate efficiency for co-firing technology with ammonia and hydrogen. Moreover, the report states that "For the time being, from the viewpoint of technological development and dissemination, it does not matter whether or not ammonia or hydrogen is carbon-free (i.e., whether it is derived from non-fossil energy, or from fossil fuel)" (p. 14). This is a reckless arrangement that would consider anything to be green, even if it results in fossil fuel-derived CO_2 emissions. The proposal was made with measures to reduce the ratio of coal in the electricity mix to 26% in 2030 under the Fifth Strategic Energy Plan. However, the government announced the carbon neutral declaration and emission reduction target of 46% to 50% by 2030, and that was followed by the

10 Advisory Committee on Natural Resources and Energy "Interim Report of the Working Group to Consider Coal Power," in Japanese, April 2021.

Sixth Strategic Energy Plan with the target mix for coal being reduced to 19%. As we see it, the measures based on this proposal give Japan neither a reduction of CO_2 emissions from coal nor a proper phase out of inefficient coal power. Bloomberg NEF (BNEF), which reports on energy, economy, and environment, has projected that under current policies, coal power will still account for 32% of Japan's electricity in 2030[11].

2. Industry actions

(1) Thermal power producers

(a) JERA

JERA was established in 2015 by TEPCO and Chubu Electric Power Co. In 2019, the two companies fully integrated their thermal power generation businesses, including the value chain of upstream fuel procurement, electricity generation, and wholesale business for electricity and gas. Owning half of the thermal power generation capacity in Japan, this is now Japan's largest thermal power producer -large even on a global scale in terms of fuel volume handled. The "JERA Zero CO_2 Emissions 2050" announcement was also made in October 2020, closely timed with then-Prime Minister Yoshihide Suga's carbon neutral declaration[12].

With a target of reducing CO_2 emission intensity by 20% by 2030, the roadmap aims to close and decommission inefficient coal-fired power plants by 2030 and promote offshore wind, as well as co-firing of ammonia with coal or hydrogen with gas-fired power generation, aiming for ammonia and hydrogen exclusively in 2050 (while using carbon offsets or CO_2-free LNG for any portion that cannot be 100% ammonia and hydrogen in 2050). In May 2021, with a four-year grant from NEDO for June 2021 to March 2025, JERA launched a project to co-fire coal and ammonia at Unit 4 (1GW) of the Hekinan Thermal Power in Aichi Prefecture, aiming to achieve co-firing with 20% ammonia in the fuel mix in 2024[13]. JERA is responsible for ammonia procurement and construction of related facilities such as storage tanks and vaporizers, while IHI's role is to develop burners to be used in the demonstration. The press release presents this as the world's first demonstration project for a large volume of ammonia to be co-fired in a large-scale commercial coal-fired power plant. Meanwhile, no details have been provided yet regarding hydrogen co-firing with gas, including the timing of any demonstration project. To secure ammonia as fuel, JERA also has an agreement to collaborate with Malaysia's state-owned oil and natural gas company Petronas and Norwegian fertilizer giant Yara International to build an ammonia supply chain.

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11 Miho Kurosaki presentation, "Carbon neutral growth strategy: Challenges and path to achievement" (BNEF Japan Forum 2021, September, 2021).

12 ERA, "JERA Zero Emissions 2050," October 2020.

13 JERA, "JERA and IHI to Start a Demonstration Project Related to Ammonia Co-firing at a Large-Scale Commercial Coal-Fired Power Plant," May 2021.

(b) J-POWER

J-POWER, the next largest thermal power producer in Japan after JERA, announced "Blue Mission 2050" in February 2021[14]. With the target of reducing CO_2 emissions by 40% by 2030 and making its power generation business carbon-neutral by realizing carbon-free hydrogen power generation by 2050, the plan is to promote renewable energy while phasing out and reducing aging coal-fired power plants, as well as to promote the Ohma Nuclear Power Plant Project currently under construction, to produce and supply hydrogen, and promote electricity generation from hydrogen. However, activities currently being promoted are for hydrogen production and electricity generation using coal gasification technology on projects such as an Australian brown-coal hydrogen pilot demonstration project and a CO_2 storage demonstration and technology development project. The company is working on the Osaki CoolGen Project, a coal-gasification fuel-cell combined power generation demonstration project which started in 2012 with the aim of promoting "innovative low-carbon coal power generation," and is expecting to proceed to use that technology to generate electricity with hydrogen. But ultimately, if hydrogen is being produced from coal, CO_2 will be emitted. As for the CO_2 that is emitted, the company is saying the plant would be "CO_2-free" on the premise that carbon can be stored in Japan or overseas. However, its feasibility is by no means assured.

The Matsushima Thermal Power Plant that started operating in 1981 in Saikai City, Nagasaki Prefecture is J-POWER's oldest power plant. In April 2021, the company announced the GENESIS Matsushima Project to install coal gasification equipment to produce fuel gas and generate electricity[15]. The environmental impact assessment process began in September 2021, with plans for construction to start in 2024, and operational launch slated for 2026[16]. As mentioned above, since the government has a policy of phasing out inefficient coal power, one would expect older power plants like this one to be shut down quickly, but with new projects like this one being dubbed the "first step toward the goal" of hydrogen power generation under this plan, the company is promoting a project to further extend the life of the company's oldest coal-fired power plant.

(c) Other companies joining the fray

Other companies are also rushing into initiatives including resource and supply chain development related to hydrogen and ammonia, as well as CCUS.

Since 2014, Mitsubishi Corporation has participated in the LNG Canada project, which aims to be the first export of Canadian shale gas, and involves a shale gas development in an inland region of British Colombia and a 670 km pipeline to connect to a terminal on the west coast for export to Asia[17]. Although critics of pointed out violations of human rights of First Nations as

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14 J-POWER, "Blue Mission 2050," February 2021.

15 J-POWER, "J-POWER Starts Preparation for Environmental Impact Assessment of GENESIS Matsushima Plan" April 2021; Kiko Network, "Send in your comments on the GENESIS Matsushima Project," in Japanese, October 2021.

16 J-POWER, "Environmental Assessment for GENESIS Matsushima Project," in Japanese, September 2021.

17 Mitsubishi Corporation website, Montney shale gas development project/LNG Canada project.

well as destruction of the environment[18], JERA and Tokyo Gas have reached a basic agreement to purchase LNG from this project, and JOGMEC is to provide loan guarantees, while both public and private Japanese financial institutions are also planning to provide financing. In August 2021, Mitsubishi Corporation and a business consortium received approval for an LNG project development project in Indonesia[19]. The project is anticipated to increase natural gas production. In September 2021, Mitsubishi Corporation together with the Anglo-Dutch multinational oil and gas company Royal Dutch Shell announced plans to build a hydrogen production facility near the Canadian city of Edmonton, Alberta, and use natural gas purchased from local suppliers and Shell to produce hydrogen, convert it into ammonia, import it into Japan, and supply it as fuel ammonia (Fig. 1)[20].

Mitsui & Co. and JOGMEC have agreed to conduct a joint survey on CCS with a view to commercialize clean fuel ammonia production in Western Australia. A contract has been signed between MEPAU (100% subsidiary of Mitsui & Co.) and JOGMEC. As well, MEPAU has agreed with WesCEF on a commercial feasibility study on fuel ammonia production in Western Australia, and the two companies have exchanged a memorandum of understanding. Specifically, the intention is to reform natural gas produced in the Waitsia gas field, store the CO_2 emitted in the process in a waste gas field, to produce and export clean fuel ammonia[21].

ITOCHU Corporation, in collaboration with the Irkutsk Oil Company, JOGMEC, and TOYO Engineering, is designing the concept of producing hydrogen and ammonia from natural gas from oil fields in eastern Siberia in Russia, and is considering using rail and a pipeline to transport ammonia inland (Fig. 2). At the same time, it plans to establish a blue ammonia value chain in combination with enhanced oil recovery (CO_2-EOR) to increase oil production[22].

Marubeni, together with JOGMEC, Hokuriku Electric Power Co., and Kansai Electric Power Co., is conducting a commercial feasibility survey for the entire supply chain to produce ammonia from Australian natural gas, transport it to Japan by ship, and supply it for power generation and marine fuel use. CO_2 emitted in the process of ammonia production is to be converted to clean fuel by technologies including CCUS[23].

With a METI grant for quality infrastructure, IHI joined with Petronas Gas & New Energy (a subsidiary of Malaysia's state-owned oil and gas company Petronas) and TNB Genco (a subsidiary of Malaysia's leading electric power company TNB) to begin assessing technology for co-firing am-

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18 FoE Japan website, LNG Canada Project. in Japanese.

19 Mitsubishi Corporation, SKK Migas approved Plan of Development for Ubadari Field and Vorwata CCUS at Tangguh LNG Project," August 2021. Consortium includes INPEX Corporation, Mitsui & Co., Sumitomo Corporation, Sojitsu Corporation.

20 Mitsubishi Corporation, "Mitsubishi Corporation and Shell sign MoU to collaborate on hydrogen plans in Alberta," September 2021.

21 Mitsui & Co., "Joint Feasibility Study for Creation of a Supply Chain of Low Carbon Ammonia in Western Australia," October 2021.

22 ITOCHU Corporation, "Initiation of Joint Feasibility Study in Phase 2 of Blue Ammonia Value Chain between Eastern Siberia and Japan," July 2021.

23 Marubeni, "Feasibility Study on Establishing a Clean Fuel Ammonia Supply Chain from Australia to Japan," July 2021.

monia at coal power stations in Malaysia and evaluating technologies and economic viability across the entire supply chain, including the production of "green ammonia" from renewable energy sources and "blue ammonia" from natural gas[24]. JERA has signed a memorandum of understanding with Petronas to cooperate on the production and supply of ammonia and hydrogen. Furthermore, in April 2019, the Clean Fuel Ammonia Association was established with the aim of "building a value chain for CO_2-free ammonia," and all related businesses are participating.

Today we are seeing electric power companies, trading companies, plant manufacturers, and others scrambling to get into hydrogen and ammonia-related businesses. However, the reality is that these businesses are essentially an extension of the fossil fuel development business.

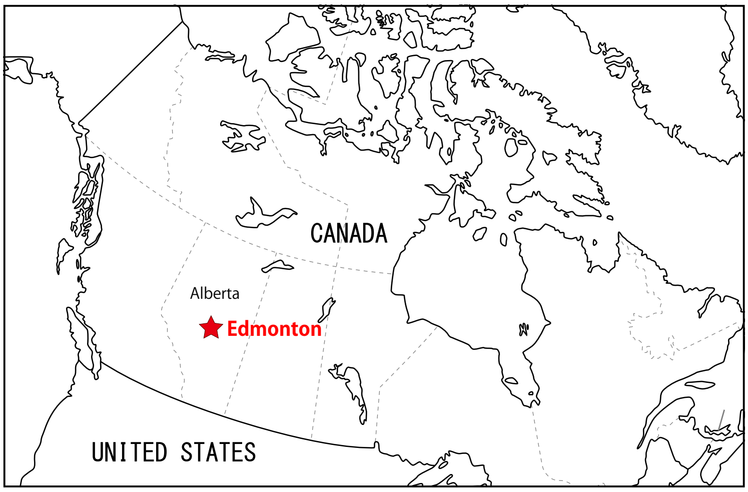

Fig. 1. Map of locations of Mitsubishi Corporation's hydrogen plant construction sites for the supply of fuel ammonia. Source: Prepared by Kiko Network based on Mitsubishi Corporation website.

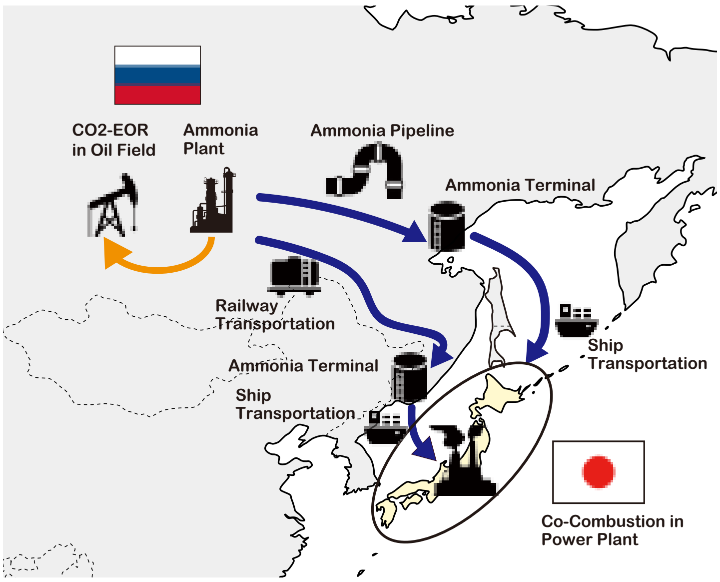

Fig. 2. Map of ITOCHU Corporation's hydrogen and ammonia production from natural gas from eastern Siberia, and inland transport routes. Source: Prepared by Kiko Network based on ITOCHU Corporation website.

24 IHI, "IHI and Partners Launching Ammonia Co-Firing Technology Feasibility Assessments at Coal Power Stations in Malaysia with Partners and for Other Companies to Establish Local Carbon-Free Ammonia Supply Chain," October, 2021.

(d) Financial institutions and insurance companies

In response to the international push to decarbonize, Japan's three megabanks have already announced policies to stop investing in coal power. They have also declared policies of calculating GHG emissions in their investment and loan portfolios, and are expected to continue setting medium-term targets and formulating indicators in line with the Paris Agreement's 1.5°C goal and carbon neutrality by 2050.

Nevertheless, they have also revealed policies of supporting innovations such as ammonia and hydrogen technologies. Among non-life insurance companies, Tokio Marine Holdings Inc. has placed restrictions on coal mine development (thermal coal), but allows exceptions for innovative technologies and methods (Table 1). If, in the name of supporting the transition, the support is provided without the banks properly verifying whether or not the projects will produce credible CO_2 emission reductions, there is a serious risk that it will fail to result in substantial emission reductions, or even increase investment and financing for fossil fuel projects that are highly problematic as responses to climate change, and keep coal power running. In particular, strict measures are needed to ensure that bank support for hydrogen, ammonia and CCUS projects does not end up being a loophole in policies intended to reduce coal power credit balances to zero.

Table 1. Innovation support policies of three megabanks and Tokio Marine Holdings, Inc.

Financial institution	Innovation support policies
Mitsubishi UFJ Financial Group, "Integrated Report 2021," March 2021.	* Strengthen financing to realize innovation in hydrogen, next-generation energy and carbon recycling, etc. * Regarding innovation, consider and implement new financial service schemes in tandem with customers, with the aim of supporting new business endeavors, including R&D and verification testing, to contribute to the realization of carbon neutrality
Mizuho Financial Group "Strengthening our sustainability action," May 2021.	* If a proposed coal-fired power plant is essential for a country's stable supply of energy and will contribute to a reduction of GHG emissions by replacing an existing power plant, we may provide financing or investment for the project, based on careful consideration. * Continue to support development of innovative, clean, and efficient next generation technology … for the transition to a low-carbon society
Sumitomo Mitsui Financial Group "TCFD Report 2021," October 3, 2021	* Support R&D that contributes to carbon neutrality, including carbon capture and storage (CCS)
Tokio Marine Holdings Inc., Revision of "Tokio Marine: Our Climate Strategy" September, 2021	* Will carefully consider exceptions for (thermal) coal mining projects, limiting the scope only to projects with the innovative technologies and approaches necessary to achieve the goals of the Paris Agreement.

Prepared by Kiko Network

3. Constraints on the climate

(1) Coal- and LNG-fired power generation in Japan today

To date, Japan has continued to increase its use of and reliance on coal and liquefied natural gas (LNG) for power generation. In the fiscal year 2019, coal accounted for 32% and LNG 37% of the electricity mix. Coal-fired power generation alone accounts for nearly a quarter of Japan's total CO_2 emissions and is the largest source of its emissions. After the Fukushima Daiichi nuclear accident in 2011, construction went ahead on many new power plants, most of which used coal as a power source. Plans surfaced for 50 new coal-fired generation units starting in 2012, 17 of which have been canceled at the planning stage, but more than 20 have started operating, and 9 are currently under construction[25].

According to power supply plans based on notifications from electric utilities compiled by the Organization for Cross-regional Coordination of Transmission Operators (OCCTO), the installed capacity of coal and LNG is expected to be higher in 2030 than it is today. From this one can deduce that operators are trying to increase the amount of coal power, with the anticipation that coal-fired power generation costs will stay relatively low and without considering the likelihood of new regulatory measures being imposed. There is a significant difference in trends for coal and LNG. The fleet capacity factor (or utilization rate) of coal-fired power plants in 2030 is expected to remain extremely high at 65%, but drop to 35% for LNG. If circumstances go according to plan, the amount of electricity generated (transmission side) in 2030 will be 302.2 TWh (34% of the power mix) from coal and 256.5 TWh (29%) from LNG.

In Japan's Sixth Strategic Energy Plan, the government plans to revise the power mix in 2030 to reduce coal from the original 26% to 19% and LNG from 27% down to 20%. However, the transmission operators' supply plans as compiled by OCCTO tell a completely different story. Furthermore, as described below, the plans completely fall short of what is needed when considering the reduction levels required to address the climate crisis.

(2) Coal phase-out by 2030 needed to limit warming to 1.5°C

The climate crisis is intensifying. The United Nations Environment Programme (UNEP) has stated that GHG emissions in 2019 were 52.4 Gt-CO_2e, with CO_2 emissions alone at 38 Gt-CO_2, but global GHG emissions must be halved about 25 Gt-CO_2e by 2030 to be 1.5°C consistent[26]. In addition, the latest scientific findings of the Working Group 1 report for the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), released in August 2021, show in detail that that if the temperature rise exceeds 1.5°C, the impacts will be so serious they could overwhelm human society's capacity to respond. The report also makes it clear that the remaining carbon budget (allowable emissions) of CO_2 to keep the temperature rise to 1.5°C ranges between

25 Japan Beyond Coal, power plant map & data, as of September 2021.
26 UNEP, Emission Gap Report 2020, p.25-28.

300 Gt-CO_2 (83% likelihood) and 400 Gt-CO_2 (67% likelihood). If we continue emitting at the current rate, the remaining carbon budget will be exhausted.

Climate Analytics, a climate think tank, pointed out early on that in order to be compatible with the 1.5°C goal, developed countries would need to phase out coal-fired power generation by 2030, and the rest of the world would have to do so by 2040[27]. In its Net Zero by 2050" [28] report released in May 2021, the International Energy Agency (IEA) sets out a roadmap for fossil fuels in the energy sector to be significantly reduced and mostly replaced by renewable energy. The roadmap states that no new investment is needed for the supply of fossil fuel, and that coal-fired power generation needs to be phased out. As a milestone to 2050, the roadmap shows that all unabated coal-fired power plants (those that do not have carbon capture and storage technology, or CCS) in developed countries need to be phased out by 2030, with net zero achieved in the electric power sector in developed countries by 2035, and all unabated thermal power generation (coal and gas without CCS) phased out by 2040. It is basically a given that coal-fired power generation must be completely phased out.

4. Problems with hydrogen and ammonia

(1) CO_2 emissions and reductions with hydrogen and ammonia

Hydrogen and ammonia do not emit CO_2 during electricity generation, so domestic emissions during generation will be reduced accordingly if they are co-fired with thermal power generation. However, if hydrogen and ammonia are produced from fossil fuels, CO_2 will be emitted during production. As described above, the presumed production of hydrogen and ammonia is based on fossil fuels such as brown coal (lignite) in Australia and LNG in Russia and Canada, so even if emissions are reduced domestically in Japan, CO_2 would still be emitted in the other countries. Hence, the apparent reductions in Japan would just be an illusion. Below we make an estimate of the CO_2 emission reduction effects of fossil fuel-derived hydrogen and ammonia based on certain assumptions.

(a) Estimated CO_2 emissions from ammonia co-firing with coal

Based on material from the Ministry of the Environment and other sources, total emissions per ton of ammonia produced would be 1.58 t-CO_2, considering emissions associated with raw materials and emissions from machinery and thermal use during production (Table 2)[29].

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27 Climate Analytics, "Global and regional coal phase-out requirements of the Paris Agreement: Insights from the IPCC Special Report on 1.5° C," September 2019.

28 IEA, "Net Zero by 2050: Roadmap for the Global Energy Sector," May 2021.

29 While METI does not provide the basis for its numbers, the "Blue Ammonia Production Technology Development" Technical evaluation report (preliminary evaluation) for research and development program for budget request documentation for FY2022" report (in Japanese) states that even state-of-the-art equipment

Table 2. CO_2 emissions per ton of ammonia produced (t-CO_2)

Emissions from raw materials production (A)	Emissions from processing (B)	Total CO_2 emissions (A+B)
1.14	0.44	1.58

Note: Estimates are based on calculations by Japan's Ministry of the Environment[30]. However, emissions would be about 35% higher if calculated based on CO_2 emissions from Japan's ammonia production.

Prepared by Kiko Network

Based on this, if a 20% ammonia fuel mix is co-fired in a 1 GW ultra-supercritical (USC) coal-fired power plant, CO_2 emissions would be lower by 20%, as ammonia does not emit CO_2 at the power generation stage. However, it is difficult to expect commercial applications of CCUS to be available by 2030, so CO_2 will be emitted in the producing country when ammonia is produced. If emissions are counted without CCUS, the reduction in CO_2 emissions by 20% co-firing with ammonia only comes to about 4% (Table 3, Fig. 3).

Table 3. Case study of CO_2 emissions from co-firing with ammonia (1 GW coal-fired power plant)

		Fuel	Units	Coal only	20% co-fired	50% co-fired	Ammonia only
CO_2 emissions from power generation	Co-firing ratio (calorific value)	Coal	%	100	80	50	0
		Ammonia	%	0	20	50	100
	Consumption	Coal	Mt	2.12	1.69	1.06	0
		Ammonia	Mt	0	0.49	1.23	2.46
	CO_2 emissions/year		Mt	4.92	3.93	2.46	0
CO_2 emissions during ammonia productio	CO_2 emissions/yea		Mt		0.78	1.95	3.90
	CO_2 emissions/year (reduction rate)		Mt	4.92 -	4.71 (-4%)	4.41 (-10%)	3.90 (-21%)

Note: Total annual power generation assumed to be 6,132 GWh. Prepared by Kiko Network

emits 1.6 tons of CO_2 to produce 1 ton of ammonia.

30 Ministry of the Environment, "Greenhouse Gas Emission Calculation, Reporting Manual (Ver4.7)" Vol. 2, p. II-57, Ministry of the Environment, Calculation, Reporting of Greenhouse Gas Emissions, Sequestration, IPPU Sector "2.B.1. Ammonia Production" (in Japanese).

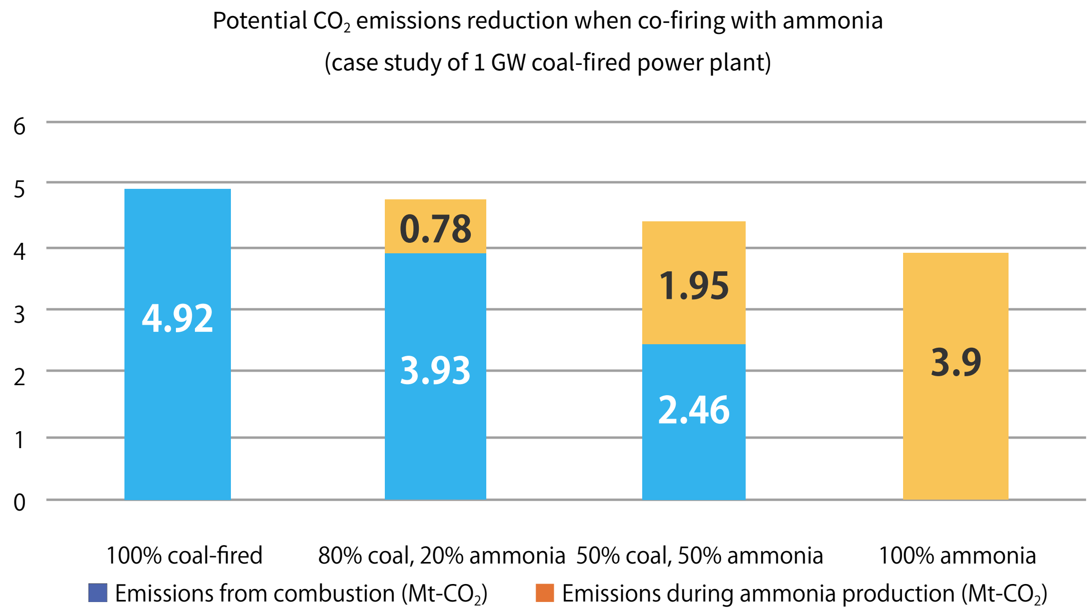

Figure 3. Potential CO_2 emissions reduction when co-firing with ammonia (prepared by Kiko Network)

Table 4. Projected CO2 emissions from coal power in 2030

		Total (39 units)
Capacity (GW)		2951
CO_2 emissions (Mt-CO_2)	Coal-fired only	1.75
	20% ammonia co-fired, 80% coal	
	During power generation (20% reduction)	1.39
	During power generation + ammonia production (4% reduction)	1.68

Note: Excluding all inefficient coal power units (Sub-C, SC) currently operating, a total of 21 GW from 132 units. Prepared by Kiko Network.

* Assuming all are operating in fiscal 2030.

* Major utilities (all 9 former electric power companies + J-POWER) (35 units) + Kobelco (2 units) + IGCC (2 units) = 39 units

* Capacity factor (utilization rate) 68%, emission intensity 0.785 kg-CO_2/kWh

If all inefficient coal power generating units in Japan are phased out and only USC units currently operating, planned or under construction are still operating in 2030, CO_2 emissions from coal power with 20% ammonia co-firing will be 123 Mt-CO_2 (about 10% of total GHG emissions in FY2018), a reduction of only 31 Mt-CO_2 (2.5% of Japan's total GHG emissions in FY2018). Furthermore, if we add emissions from raw material production and processing overseas until CCUS actually becomes viable, the contribution to any emission reduction is negligible, at about 6.6 Mt-CO_2. In short, co-firing with ammonia offers only a minimal contribution to any CO_2 emission reduction.

Column 2. UN Climate Champions: Guiding principles for 1.5°C-aligned hydrogen deployment*

The UN has appointed two persons in high level positions as Climate Champions to accelerate climate actions by diverse actors. The current Climate Champions and the Marrakech Partnership released the “Guiding Principles for Climate-Aligned Hydrogen Deployment,” which includes the following seven principles:

1. Hydrogen deployment should be targeted in applications where other solutions do not currently exist. Stakeholders should provide a clear assessment to evidence that this is the case.
2. Rigorous accounting of lifecycle emissions from hydrogen production, and ambitious ceilings on those emissions, are key to prioritize climate-aligned hydrogen deployment.
3. Renewable hydrogen is the only option strictly aligned with a reliably 1.5-degree energy sector pathway.
4. Hydrogen market designs and business models should seek to avoid overbuilding infrastructure, and inefficient re-purposing where a long-term role for renewable hydrogen is not clearly established, by adopting a medium- and long-term view on the trajectory of existing solutions.
5. Time is crucial. Policymakers need to focus on getting targeted projects off the ground and ‘learning by doing.’
6. Developing a hydrogen sector must simultaneously focus on delivering public health, workforce and global equity outcomes.
7. Hydrogen plans must be developed through transparent and accessible processes to ensure accountability to citizens.

The commentary on the fourth guideline points out that there are uncertainties in the cost-effectiveness of making long-term investments into hydrogen transport infrastructure such as hydrogen pipelines and repurposing of existing gas pipeline. Policymakers and regulators should exercise caution with any proposals for near-term expansion of inefficient fossil fuel infrastructure based on expectations of future repurposing. The document also points out that because of uncertainties in the geospatial distribution of hydrogen demand and supply centers, it is premature to engage in large-scale and near-term buildout, as such investments risk becoming stranded assets. These principles should ring alarm bells even louder about the direction Japan is currently headed.

*UN Race to Zero “UN Climate Champions launch ‘guiding principles’ for climate-aligned hydrogen,” October 2021.

(b) CO_2 emission estimates from hydrogen co-firing with coal

The only current plan to use hydrogen gas for coal-fired power generation is the GENESIS Matsushima Project mentioned above. It is believed that full-scale hydrogen power generation will require the addition of reaction equipment for hydrogen-rich processes and the replacement of turbines, but this plan does not clarify these points. Nevertheless, the GENESIS Matsushima Project has been launched in the name of taking the first step toward hydrogen power generation. As with ammonia, hydrogen also emits CO_2 if it is produced with fossil fuels. The GENESIS Matsushima project involves importing low-grade brown coal from Australia and also producing hydrogen in Australia and transporting it to Japan, and the entire initiative is deemed to be clean based on the premise that any emitted CO_2 will be later be captured and stored through CCUS.

One paper estimated CO_2 emissions when hydrogen is produced using subbituminous coal or brown coal, and found that if hydrogen is produced from brown coal and CO_2 capture by CCS is used, CO_2 emissions would be reduced by 65% relative to the direct combustion of coal, but without CCS, CO_2 emissions would range from 76% to 126% relative to the combustion of coal, showing that either there would be little difference, or in fact emissions could actually increase[31]. This means that if hydrogen is produced from Australian lignite and used regardless of whether or not the hydrogen is carbon-free and before CCUS is commercially viable, there is virtually no difference compared to emissions of CO_2 from unabated coal-fired power generation.

(2) Other issues

(a) Environmental and social impacts

The use of brown coal and natural gas has a variety of adverse environmental impacts during transportation, including resource extraction and transport, which includes pipeline construction. There are also concerns about land use, including issues about infringing on the rights of indigenous peoples. For example, the previously-mentioned LNG Canada project involves the extraction of shale gas in Canada, transporting it over long distances by pipeline, and exporting it as LNG. Shale gas extraction results in significant environmental impacts, including climate change (due to methane emissions), earthquake-induced risks, water pollution (due to fluid injection for hydraulic fracturing [fracking]), and air pollution.

It has also been pointed out that the construction of pipelines infringes on the land rights and human rights of indigenous peoples, and the issues are too big to justify investment from the perspective of Environmental, Social, and Corporate Governance (ESG)[32]. Similarly, coal and gas developments in Australia have had major adverse impacts not only on rivers, farmland and traditional settlements, but also on human health, the rights of aboriginal peoples and workers, and the destruction of ecosystems[33]. If the use of brown coal and gas is promoted due to their purported low cost, these impacts will be exacerbated.

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31 Burmistrz, P. et al. Carbon footprint of the hydrogen production process utilizing subbituminous coal and lignite gasification, Journal of Cleaner Production, 139(2016) 858-865. This paper makes estimates based on GE Energy/Texaco and Shell technologies.

32 Ibid. Footnote 18.

33 Kiko Network "Out of sight, out of mind: Impacts of Japanese use of Australian Coal," June 2021.

(b) Cost concerns

The government has also acknowledged that the use of hydrogen and ammonia as fuel for power generation is extremely expensive at this time. Costs are incurred at each stage of manufacturing overseas, transportation, and then from equipment at power plants. The government has hypothetically estimated the costs of electricity generated at 12.9 yen/ kWh for 20% ammonia co-firing with coal, at 23.5 yen/ kWh for 100% ammonia, at 20.9 yen/ kWh for 10% hydrogen co-firing with coal, and at 97.3 yen/ kWh for 100% hydrogen[34].

An analysis by BNEF found that hydrogen produced from fossil fuels costs from US$1 to $3/ ton, and the processing of CO_2 emissions with CCUS or other technologies adds further costs[35]. The analysis showed that while at present, this is considerably less expensive than the cost of producing hydrogen from renewable energy, the costs of renewable energy are expected to continue declining to the point that by 2030, hydrogen from renewable energy will be less expensive than from fossil fuels in major countries including Japan, and by 2040, it is projected to be less expensive than hydrogen from fossil fuels, even when CCUS costs are excluded. In addition, hydrogen has a low energy density, so it requires three to four times the tank capacity and marine transport capacity relative to natural gas. The volume can be reduced by liquefying hydrogen to be transported, but vaporization (re-gasification) also requires energy, resulting in overall costs being significantly higher than for natural gas. Converting hydrogen to ammonia makes it easier to transport, but it has been projected that hydrogen from domestically produced renewable energy will be cheaper due to the additional costs of converting ammonia.

Greenpeace has estimated the cost of co-firing with ammonia in coal-fired power plants[36] . Compared to US$73 /MWh as the mid-level average levelized cost of energy (LCOE) in ultra-supercritical (USC) plants, they projected that co-firing with 20% fossil fuel-derived ammonia will increase costs to $98/MWh, further increasing to $106/ MWh if CCUS is included. Their conclusion was that co-firing with ammonia is nothing but “expensive greenwash.”

(c) Market creation and expansion

According to government data, the world’s annual production of feedstock ammonia is about 200 million tons, of which 10% (about 20 million tons) is traded, meaning most of the production is locally produced for local consumption[37]. Japan consumes 1.08 million tons of feedstock ammonia annually, of which 80% is produced domestically, and its imports amount to only 235,000 tons. One coal-fired power plant would require 500,000 tons of ammonia when co-fired with 20% ammonia (in the case of a 1 GW plant), so if all power plants of the major utilities in Ja-

34 Basic Policy Subcommittee of the Advisory Committee on Natural Resources and Energy, “Consideration of achieving carbon neutrality in 2050,” December 2020.

35 Martin Tengler presentation, “Prospects for hydrogen,” BNEF Japan Forum 2021, September 2021.

36 Greenpeace, “JERA and Japan seek costly and dirty alternative to RE: Lengthening the lifeline of coal power in Japan”, March, 2021.

37 Agency for Natural Resources and Energy “Consideration for 2050 carbon neutrality”, in Japanese, December 2021, P.59-61.

pan were co-firing at 20% ammonia, an amount comparable to the entire 20 million tons of current global trade volume would be required for co-firing in Japan alone. In other words, this would require the creation of enormous new markets and supply chains for fuel ammonia. What the government is currently promoting is the creation and expansion of a huge market for ammonia production from natural gas and its transportation (Fig. 4).

The Sixth Strategic Energy Plan states that Japan intends to be a leader in creating and expanding LNG markets and promoting a realistic energy transition in Asia[38]. But like elsewhere, the cost of renewable energy is dropping rapidly in Asia. From the perspective of reducing CO_2 emissions and accelerating decarbonization in developing countries, rigorous analysis and review is required if Japan's intention is to inject more money into thermal power generation and promote co-firing with ammonia and hydrogen. In the electrical power sector, accelerating the spread of renewable energy is technically more feasible and overwhelmingly less expensive, so any investments related to the use of ammonia and hydrogen – which really serve to extend the life of the fossil fuel sector – risk becoming the next stranded assets.

Businesses and industries must contribute to the rapid transition to decarbonization. To foster a sustainable economy and industry in Japan, they need to promote sectors that focus on energy efficiency, renewable energy, and a just transition, rather than continuing with projects linked to fossil fuels.

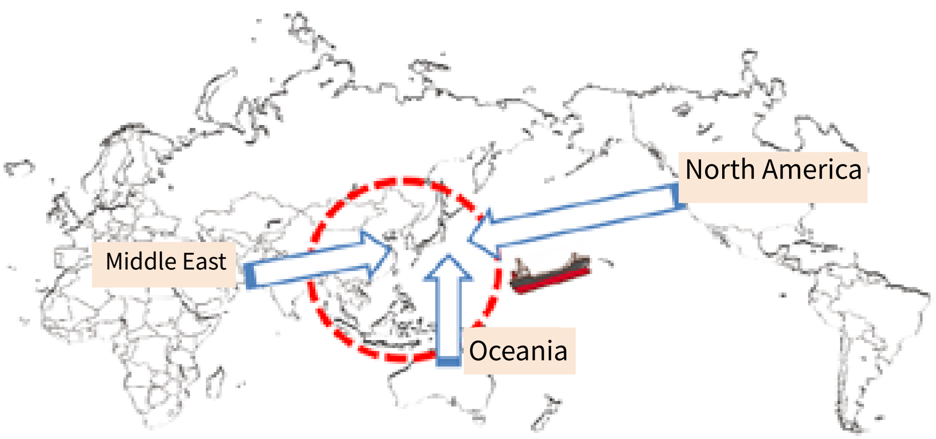

Fig. 4. LNG supply chain (based on documents from Basic Policy Subcommittee of the Advisory Committee on Natural Resources and Energy)

38 Ibid. Footnote 6. P.101.

5. Conclusion: What's really needed is an end to coal and fossil fuels

Ultimately, most of the hydrogen and ammonia that would be used for the projects currently moving ahead would be produced from overseas fossil fuels. With co-fired thermal power generation in that situation, there is virtually no net reduction in CO_2 emissions, because even though their emissions may appear to be lower in Japan, they just occur during the production stages outside of Japan. Furthermore, even if 20% co-fired power generation is realized in 2030, CO_2 emissions from the continued use of coal and LNG will still be enormous unless CCUS becomes viable on a massive scale.

It is abundantly clear that, even though hydrogen or ammonia for electricity production currently offer almost no hope of contributing to emissions reductions, they are being touted as carbon-free or zero emission solutions based on the notion that at some point in the future CO_2 will be captured and/or utilized with CCUS, or that conventional production may eventually be replaced with hydrogen or ammonia produced by renewable energy. However, there is no real likelihood that these technologies will become viable. Even with CCUS, zero emissions cannot be achieved because CCUS requires energy consumption and thus emits CO_2, there are no grounds to declare them to be carbon-free or zero emission technologies. As it stands, what we are seeing is simply a new type of fossil fuel development that also serves as an attempt to prolong the life of coal- and LNG-fired power businesses.

To allow coal-fired power generation to continue beyond 2030 would be inconsistent with efforts to achieve the Paris goal of limiting warming to 1.5°C, which requires significant GHG emission reductions by 2030. This scheme appears to be about spending enormous amounts of money on fossil fuel-related businesses that emit the most CO_2, portraying these risky technologies as saviors even though they would actually exacerbate the climate crisis, and about funneling huge investments through channels such as the Green Innovation Fund. It is based on confused logic and is entirely inappropriate as a strategy to address climate change.

The IEA has pointed out that any new fossil fuel supply projects are inconsistent with the goal of limiting warming to 1.5°C. There is an urgent need to rethink any investments in new technologies that would add to the use of fossil fuels premised on the use of thermal power generation.

With the remaining carbon budget, the only way to meet the 1.5°C goal is to completely phase out coal power by 2030 and reduce emissions in the electric power sector, including natural gas, to zero in the 2030s. We call for an immediate re-examination of government policies that are assisting these technologies, including funds going to the Green Innovation Fund. Finally, Japan should base its policies and technologies mainly on energy efficiency and renewable energy, while for hydrogen and ammonia, Japan should make the transition to investments focusing on production from renewable energy sources only.

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