KIKO NETWORK 気候ネットワーク 市民のチカラで、気候変動を止める。

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Carbon capture, utilization and storage (CCUS) is not a magic wand

No role for CCUS as a pillar of climate policy in Japan or Asia

CONTENTS

Introduction

Kiko Network issued a position paper on carbon capture, utilization and storage (CCUS) in June 2019[1]. In it, we pointed out many problems with CCUS, including effectiveness, economic viability, environmental concerns, and technical risks. We emphasized that not only is CCUS inadequate as a part of actions to address climate change, it is also inappropriate to be relied upon on or emphasized in government policy.

Nevertheless, since then, the Japanese government has been moving steadily ahead to formulate policies that would increase dependence on carbon capture and storage (CCS), trying to link it to carbon emission reductions as part of the nation's climate actions. The final report on a long-term roadmap for CCS was released in March 2023[2], and in the consideration process, besides typical CCS projects in Japan, it also points to policies aimed at implementing CCS projects overseas. The Ministry of Economy, Trade and Industry (METI) issued a final report in March 2023.

In addition, the Green Transformation (GX) Basic Policy, announced in December 2022 as the guiding direction for Japan's energy policies, presents CCS as one example of technologies to pursue in order to secure flexibility in decarbonization, along with higher efficiency of power generation, promotion of co-firing or 100% firing with hydrogen or ammonia, maintaining and increasing pumped hydro, and promoting storage batteries and carbon recycling technologies. Furthermore, in order to prime the business environment for the launch of CCS projects by 2030, the government is accelerating project development and operational support, as well as the development of a regulatory framework. It is also aiming to promote CCS projects both in Japan and abroad by applying the Joint Crediting Mechanism (JCM, a bilateral carbon credit system) to accommodate large-scale projects such as CCS.

This paper summarizes the current status of CCS implementation in Japan based on the CCS long-term roadmap and the analytical findings of international organizations and think tanks related to CCS and CCUS since we published our previous paper in 2019, and points out the problems that may arise if CCS projects multiply overseas in the future. It concludes by once again calling for a reconsideration of Japan's CCS policies.

1. Current status of CCS implementation in Japan

Regarding the domestic implementation of CCS, the problems that we pointed out in our 2019 position paper have not been resolved as of this point in time. Rather, the challenges of implementation in Japan have become increasingly apparent as consideration of CCS has moved

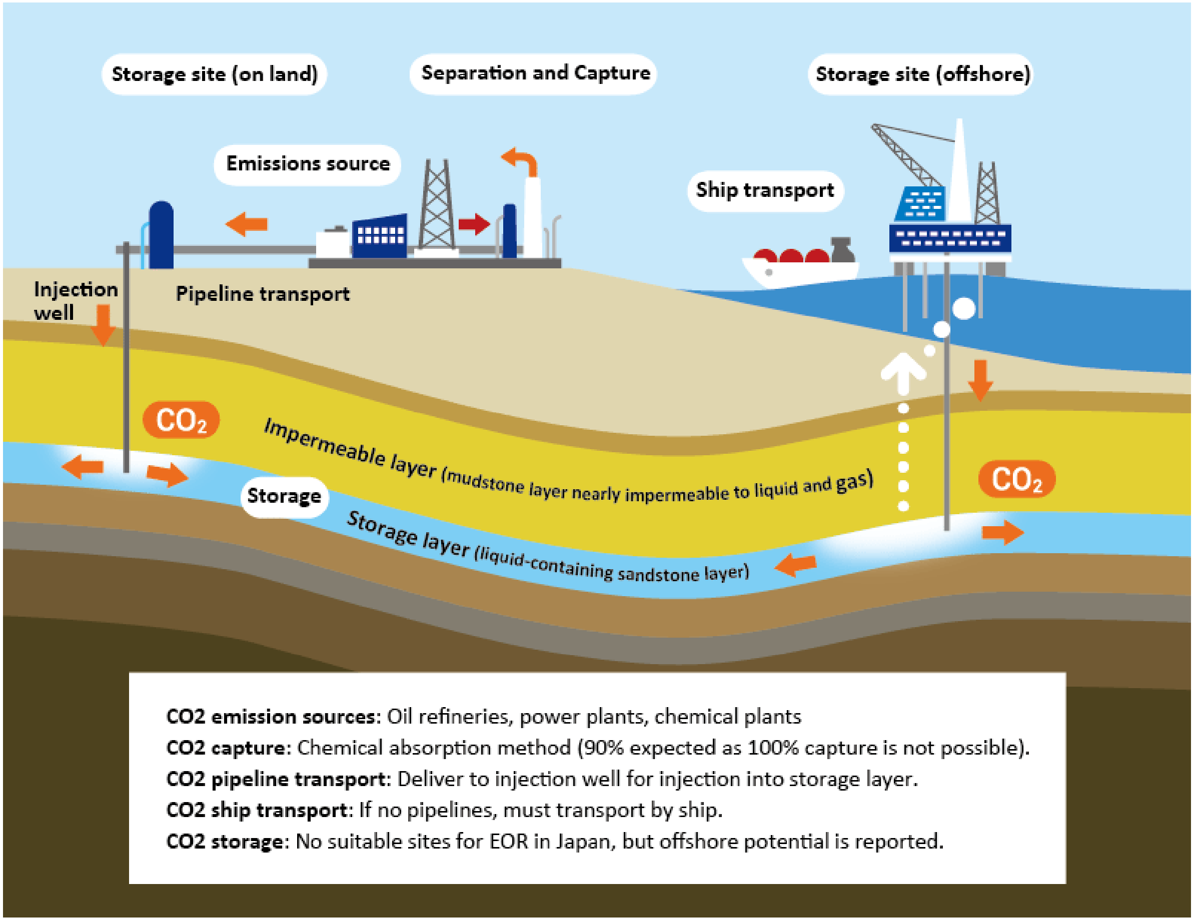
1 Position Paper—Risky Dreams: Carbon Capture, Utilization, and Storage (CCUS) (June 2019) https://www.kikonet.org/info/publication/position-paper-CCUS (in Japanese) and https://www.kikonet.org/wp/wp-content/uploads/2019/08/pp-ccus-f.pdf (in English).

2 CCS Long-Term Roadmap Study Group: Final Report (March 2023) (in Japanese) https://www.meti.go.jp/shingikai/energy_environment/ccs_choki_roadmap/pdf/20230310_1.pdf

ahead. The following is a summary of issues at each stage of the CCS process of carbon capture, transport, and storage.

Regarding the utilization of captured carbon (the U in CCU), in this paper we will just state two points. First, even the Carbon Recycling Technology Roadmap[3] [3] by METI fails to provide any projections for large-scale expansion in the near future because the technologies have not reached the commercial application stage and are still plagued by uncertainties. Second, analyses by think tanks have concluded that many issues remain unaddressed in terms of economics and lifecycle carbon and energy budgets[4].

Figure 1: Carbon capture and storage



Source: Excerpted from a fact sheet prepared by Japan Beyond Coal[5], from other sources such as Reference 1 at the 35th session of the Basic Policy Subcommittee of the Advisory Committee for Natural Resources and Energy.

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3 Ministry of Economy, Trade and Industry (METI) Carbon Recycling Technology Roadmap (revised July 2021) (in Japanese) https://www.meti.go.jp/press/2021/07/20210726007/20210726007.pdf

4 Domestic and international trends of effective use of CO_2 (CCU) by Mizuho Research & Technologies (2020) https://www.mizuho-rt.co.jp/publication/report/2020/mhir20_ccu_01.html

5 Fact Sheet – Carbon capture and storage (CCS): Its significant risk. (in Japanese) https://beyond-coal.jp/beyond-coal/wp-content/uploads/2022/09/JBC_factsheet_07.pdf

(1) Capture

According to the R&D and Social Implementation Plan related to the Green Innovation Fund Project "Development of Technologies for CO_2 Capture and Separation" by Agency for Natural Resources and Energy[6], the difficulties with CO_2 capture mainly involve exhaust gas pressure and CO_2 concentrations. Moreover, because emissions from power generation such as coal-fired and natural gas-fired thermal power plants are at low pressure, it is difficult to achieve high capture rates and economic efficiency compared to carbon capture from the hydrogen or ammonia industries or from by-product gases produced in natural gas production.

Regarding emissions from power generation, the Agency for Natural Resources and Energy (ANRE) states that CCS is already in the demonstration to commercial stages at coal-fired power plants where there are higher CO_2 concentrations in emissions. However, to date this has not been achieved within Japan, and Petra Nova[7], cited as an example of commercial operations overseas, was suspended in 2020 due to problems with profitability, with many malfunctions occurring since operations started in 2016, operations being unstable, and CO_2 capture targets not being achieved[8]. Furthermore, ANRE says that CO_2 capture at low-pressure and from low-concentration emissions of power plants fired by natural gas have not yet been established, so the component technologies still need to be developed and tested.

At present, the cost of capture is in the 6,000 yen/t-CO_2 range for low-pressure, low-concentration emissions, and estimated to be in the 4,000 yen/t-CO_2 range for plants currently being planned, with a technology development target of achieving the 2,000 yen/t-CO_2 range in 2030.

(2) Transport

The method of transporting the captured CO_2 will differ depending on where it is to be stored. If the storage site is close to land, it will have to be transported by pipeline, and if far from land, it must be liquefied and then transported by ship[9]. Since Japan has few suitable storage sites on

6 Green Innovation Fund Project "Development of Technologies for CO_2 Capture and Separation" by Agency for Natural Resources and Energy (in Japanese) https://www.meti.go.jp/press/2021/01/20220120007/20220120007-2.pdf

7 R&D and Social Implementation Plan (January 20, 2022) for "CO_2 Capture Research and Development" project (main report). (The report does not name the project, describing it only as "a coal-fired power plant in North America by a Japanese company," but Petra Nova is the only plant it could be.) (in Japanese) https://www.meti.go.jp/press/2021/01/20220120007/20220120007-2.pdf

8 Reuters "Japan's Eneos to buy out operator of U.S. CO_2 capture project Petra Nova" (September 14, 2022) https://www.reuters.com/article/japan-eneos-holdings-idUSL1N30L0RX

9 JGC Corporation, Ueno Transtech Co., Ltd., Chiyoda Corporation, the University of Tokyo and Taisei Corporation "Transportation Technology for Eco-Friendly CCS Demonstration Project" (March 5, 2019) (in Japanese) https://www.env.go.jp/earth/ccs/ccus-kaigi/2-2_CCUS_transport.pdf

land, if it is to carry out CCS on a scale envisioned by the government, it will be necessary to store carbon in geological formations offshore, remote from the coast, and that involves marine transport.

Transportation to the storage area will require the construction of new transport vessels, which is an expensive proposition. Shipping will also be affected by natural conditions such as weather and marine conditions during transport[10], so it will be difficult to guarantee stable operations.

The Research Institute of Innovative Technology for the Earth (RITE) estimates[11] the current cost of transport by ship to an offshore seabed storage site at 9,300 yen/t-CO_2 for a distance of 1,100 km and an annual storage capacity of 500,000 t-CO_2, and 6,000 yen/t-CO_2 for an annual storage capacity of 3 million t-CO_2 in 2050.

(3) Storage

In the interim report of the long-term roadmap, the government estimates Japan's annual CO_2 storage capacity in 2050 at 120 million to 240 million tons. Although the validity of this estimate itself remains in question[12], if those numbers are accepted, the government estimates that the number of injection wells capable of handling 500,000 tons per year would have to increase at a pace of 12 to 24 wells per year over 20 years from 2030 to 2050.

As for the feasibility of CCS at this scale, the only achievement to date in Japan is the Tomakomai demonstration project, where 300,000 tons of CO_2 were injected in 2019 and monitoring is being conducted. One can only question how realistic it will be to achieve those numbers.

In addition, the implementation of CCS requires solid geological formations to properly store CO_2. However, Japan is in an earthquake-prone region with many active faults, and there are few geological formations suitable for stable storage of CO_2 over long periods of time, ranging from hundreds to thousands of years. In addition, since Japan has almost no oil and natural gas development areas, there is very little capacity for storage through the enhanced oil recovery (EOR) techniques seen overseas, and very little potential for injection into depleted gas and oil fields.

Based on the surveys conducted in the final report, METI estimated storage capacity at about 16

10 Ibid. https://www.env.go.jp/earth/ccs/ccus-kaigi/2-2_CCUS_transport.pdf

11 RITE CCS value chain cost (October 31, 2022) (in Japanese) https://www.meti.go.jp/shingikai/energy_environment/ccs_choki_roadmap/jisshi_kento/pdf/003_04_00.pdf

12 The government estimates annual CO_2 storage in Japan in 2050—the basis of these projections—by multiplying 3.6 to 7.2 billion tons annually (the required global annual amount of CO_2 capture from CCS in 2050 under the CO_2 emission scenario prepared by the IEA) by 3.3% (Japan's current share of global CO_2 emissions). Therefore, it should be noted that figures such as and the numbers of required injection wells derived from the estimates are derived from the very simplified and uncertain assumption that Japan will maintain exactly the same ratio in the future global CO_2emission mix as it today.

billion tons at 11 sites, and planned to conduct further surveys of sites not yet studied[13]. However, the eleven sites identified were mainly only large marine areas[14]. Storage will be impossible without more detailed studies and exploration, as well as the construction of pressurization infrastructure such as injection wells and CO_2 transport facilities. Due to the magnitude of uncertainty at each stage leading up to any actual start of carbon storage, it is difficult to view the above-mentioned potential storage capacity even as estimates. One must admit that they are highly uncertain numbers.

For an offshore seabed storage site, RITE currently estimates storage costs at 6,900 yen/t-CO_2 for an injection well that can handle 200,000 t-CO_2 per year, and puts the cost at 5,400 yen/t-CO_2 for a facility that can handle 500,000 t-CO_2 annually in 2050[15].

Table 1. Current cost estimates for CCS

	Current cost estimates
Capture[16]	4,000 yen/t-CO_2
Transport (by ship to offshore site, distance 1,100 km, annual storage capacity 500,000 t-CO_2)	9,300 yen/t-CO_2
Storage (200,000 t-CO_2 per year, per injection well)	6,900 yen/t-CO_2
Total	20,200 yen/t-CO_2

Source: Prepared by Kiko Network from RITE CCS value chain cost (October 31, 2022)

As for monitoring of CO_2 after it is stored in offshore geological formations, technical development is still under way, but it appears to be feasible with continuous year-long monitoring based on equipment replacement four times a year[17]. However, systems would have to be put in place and cost burdens clarified in order to conduct monitoring for a total of 60 years, as envisioned in estimates by RITE, including 40 years during injection and 20 years after well decommissioning.

It is also necessary to consider the adverse effects on human populations and the surrounding

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13 Ibid. https://www.meti.go.jp/shingikai/energy_environment/ccs_choki_roadmap/pdf/20230310_1.pdf

14 CCS long-Term Roadmap Study Group: Interim Report (May 2022) (in Japanese) https://www.meti.go.jp/shingikai/energy_environment/ccs_choki_roadmap/pdf/20220527_1.pdf

15 RITE CCS Value Chain Cost (October 31, 2022) (in Japanese) https://www.meti.go.jp/shingikai/energy_environment/ccs_choki_roadmap/jisshi_kento/pdf/003_04_00.pdf

16 This estimate is based on model plant, and 6,000 Yen/t-CO_2 has been reported as an actual value. cf. R&D and Social Implementation Plan (January 20, 2022) for "CO_2 Capture Research and Development" project (main report).

17 Japan NUS Co., Ltd., National Institute of Advanced Industrial Science and Technology, and the University of Tokyo, "Environmentally Friendly Monitoring Technology for CCS Demonstration Project" (August 3, 2021) (in Japanese) https://www.env.go.jp/content/900440489.pdf

environment in the event of leaks of highly concentrated CO_2, whether on land or at sea. It is also necessary to monitor the effects of long-term storage on the geological formations. Although the government denies any causal relationship between carbon storage and earthquakes, a paper has also been published stating that further research is needed[18]. Such risks are difficult to predict, both qualitatively and quantitatively.

2. Implementation of CCS overseas, and related problems

According to the Global CCS Institute (GCCSI), as of September 2022, there were 196 commercial-scale CCS projects at the construction and development stages, up 44% from the previous year's tally[19]. Of these, only 36 projects, about one-fifth of the total, were in the electric power sector (including combined projects, two with hydrogen production and one with oil refining). Of the 36 projects, one is under construction, 12 are under development, and 23 at early phases of development[20].

Currently, the Boundary Dam Power Station in Canada is the only CCS project in the power sector worldwide that is actually operating. SaskPower, which manages the project, states that it captured about 4.8 million tons of CO_2 from the start of operations in autumn 2014 until the end of September 2022[21]. However, the project has not been able to stably capture CO_2 due to long-term shutdown as a result of equipment malfunctions and other problems, and the Renewable Energy Institute (REI) estimates the actual CO_2 capture rate over seven years at only 60%[22].

The Japanese government has designated the promotion of overseas CCS projects as one concrete action to improve the CCS business environment, and is focusing particularly on the promotion of CCS in the Asian region. On May 24, 2021, Minister of Economy, Trade and Industry Hiroshi Kajiyama announced the new Asia Energy Transition Initiative (AETI), aimed at simultaneously achieving sustainable economic growth and carbon neutrality in Asia[23]. On June 22 that year he also announced the launch of the Asia CCUS Network as an international platform for industry, academia, and government to lay the groundwork and share expertise for CCUS

18 Sano ey al. (2020) Groundwater Anomaly Related to CCS-CO_2 Injection and the 2018 Hokkaido Eastern Iburi Earthquake in Japan. Front. Earth Sci. 8:611010. https://doi.org/10.3389/feart.2020.611010

19 Global Status of CCS 2022 https://status22.globalccsinstitute.com/2022-status-report/global-status-of-ccs/

20 Global Status of CCS 2022 Appendices 6.2 2022 Facilities List https://status22.globalccsinstitute.com/2022-status-report/appendices/

21 SaskPower BD3 Status Update: Q3 2022 https://www.saskpower.com/about-us/our-company/blog/2022/bd3-status-update-q3-2022

22 Japan Renewable Energy Institute, "CCS Thermal Power Policy: Bottlenecks and Risks," April 2022 (in Japanese) https://www.renewable-ei.org/activities/reports/20220414.php

23 Ministry of Economy, Trade and Industry. "Minister of Economy, Trade and Industry Kajiyama newly announces the Asia Energy Transition Initiative (AETI)" (May 28, 2021) (in Japanese) https://www.meti.go.jp/press/2021/05/20210528007/20210528007.html

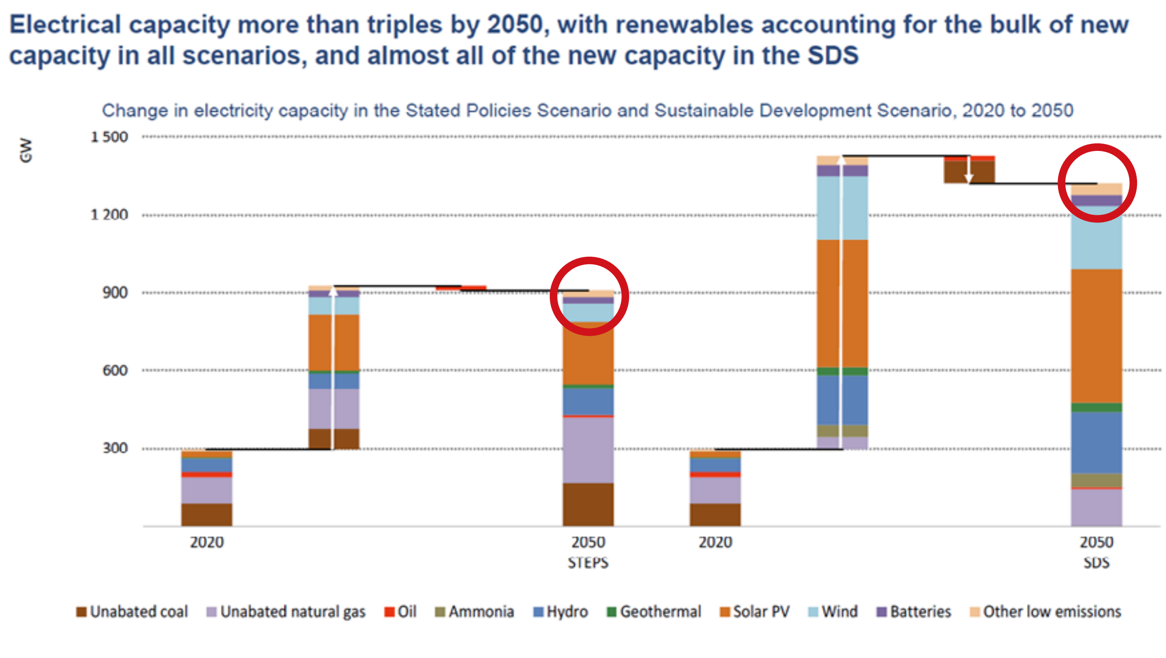
utilization throughout Asia[24].

The first problem with the overseas implementation of CCS based on these initiatives is that most of the overseas CCS projects currently at the construction or development stage are aimed at recovering CO_2 emitted from fossil fuel production processes such as natural gas refining. As a result, they could actually promote fossil fuel production.

Second, they would mean that besides Japan continuing to rely on fossil fuels imported from overseas, it would also depend on foreign countries to deal with CO_2.

Third, deploying CCS in Southeast Asia and Oceania would mean further entrenching the use of fossil fuels in these regions. Southeast Asia has high potential for renewable energy, such as hydro, wind, solar, biomass, and geothermal. The International Energy Agency's Stated Policies Scenario (STEPS) estimates that the share of renewable energy in local power generation capacity will account for about 40% in 2050, up from about 25% today. Meanwhile, its Sustainable Development Scenario (SDS) projects renewable energy at 85%, although additional effort will be required to get there. At any rate, in either scenario, the percentage of CCS accounts for only a few percent of the region's generation capacity in 2050 (indicated as just a portion of the salmon pink area in the red circle in Fig. 2 below)[25]. The future of CCS in this region is undeniably very limited.

Fig. 2 Changes in generation capacity under the published policy scenario and the sustainable development scenario (2020 - 2050)



Source: IEA, Southeast Asia Energy Outlook 2022.

24 Ministry of Economy, Trade and Industry: "Asia CCUS Network launched" (June 22, 2021) (in Japanese) https://www.meti.go.jp/press/2021/06/20210622005/20210622005.html

25 The salmon pink band showing "Other low emissions" in Fig. 2 includes nuclear, CCUS and other forms of renewables, but the combined total is only a few percent of the total. https://www.iea.org/reports/southeast-asia-energy-outlook-2022

3. Conclusions

(1) The perils of estimating required storage amounts

The government estimates that the amount of CCS storage required by Japan by 2050 will be between 120 and 240 million tons per year, and these figures are the basis for the government's consideration of CCS-related projects. However, these figures are derived from highly simplified and uncertain assumptions, as mentioned above. They are not figures that should be used as a premise for projects that are expected to cost in the range of 100 billion to 100 trillion yen in national public funds in the future.

(2) Unpredictable implementation

As shown in this stage-by-stage review of problems, there are factors at every stage that would shake anyone's confidence in the reliability of implementation of CCS. Even in previous cases overseas, major problems have hindered stable operations. At present, Japan needs to reduce CO_2 emissions as quickly as possible, with a view to achieving net zero by 2050. To this end, more emphasis should be placed on energy-saving measures based on more robust and proven technologies and the spread of renewable energy.

(3) Economics

According to RITE's estimates for CCS, the cost of storing 1 million to 3 million t-CO_2 per year is about 410 billion to 1.13 trillion yen for emissions from coal combustion, and about 720 billion yen to 2.0 trillion yen for emissions from LNG combustion. Based on annual storage of 120 to 240 million and capture of 1 million tons of CO_2 (coal-fired gas approx. 410 billion yen, LNG-fired gas 720 billion yen) in line with current government estimates, by simple calculation, enormous costs would be incurred over the 60-year operation and post-decommissioning management period, at about 49.2 to 98.4 trillion yen in the case of emissions from coal-fired combustion, and about 86.4 to 172.8 trillion yen in the case of LNG combustion.

RITE estimates, on which the government mainly bases its cost reviews of CCS projects, do not include items that clearly increase costs related to capture, transport, and storage, while they contain unrealistic assumptions and many conditions that suppress the cost estimates[26]. There is

26 For example, no costs related to land related compensation, etc., are taken into account; contingency costs that are generally budgeted into development projects that don't yet have a track record (about 35% of all costs for capture, transport, and storage) are not considered; the improbable number of just one offshore platform is calculated as being required for the expected injection volumes and the corresponding number of injection wells; the accuracy of estimates of monitoring costs is low; and costs of transporting CO_2 by ship, which would be expected in many cases of CCS in Japan, are not included in the study

a great possibility that when CCS projects are actually implemented, final costs will exceed the estimates.

No CCS cost reduction targets have been achieved to date since CCS initiatives began in the 1980s. Based on the premise that CCS projects for fossil fuel thermal power generation cannot become economically viable, plans should be devised to phase out those power plants that are the sources of emissions.

(4) Hindering decarbonization in Southeast Asia

Currently, Japan is actively trying to promote CCS in Southeast Asia, but as mentioned above, the region has huge potential for renewable energy. In addition, CCS has very little to contribute in the power generation sector, and in fact the implementation of CCS might end up being used to further promote fossil fuel resource developments such as through enhanced oil recovery (EOR). Instead of CCS, Japan should focus on contributing to options that directly support the transition to renewable energy, such as investing to improve regional power grids.

(5) In closing

Because there are currently so many problems and issues with CCS, the implementation of CCS projects should be limited only to those industrial sectors where decarbonization is most difficult. G7 countries, including Japan, are committed to decarbonizing the electricity sector by 2035 and, with a view to achieving national reduction targets (known as NDCs) by 2030 and transitioning the electricity sector to net zero, they have agreed to implement a concrete and timely phase-out of domestic 'unabated' coal-fired power plants[27]. It is clear that under the current circumstances, CCS can only make a very limited contribution to Japan's achievement of these targets in those time periods. In addition, the Japanese government is currently planning to promote CCS overseas, especially in Southeast Asia, even though it has become clear that CCS can only make a limited contribution to decarbonization in that region as well. Currently, the government is trying to complete the formulation of a long-term roadmap with high hopes placed on CCS, but a change of course is needed in such flawed policies as soon as possible.

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27 2022 G7 Leaders' Communiqué https://www.mofa.go.jp/mofaj/files/100364051.pdf

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Main Author: Hiromitsu Miyajiri
July 2023 (revised Japanese) July 2023 (revised English)*
Web: https://www.kikonet.org
Tel: 81-3-3263-9210
Fax: 81-03-3263-9463
Email: tokyo@kikonet.org

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