

Developing E-Methane Value Chain and Proper Greenhouse Gas (GHG) Accounting Rules Incentivizing Recycled Carbon Fuels

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ABSTRACT: Many countries and industries in the world are aiming to transition to a carbon neutral society. One of the means to achieve this is the use of recycled carbon fuels (RCFs) such as e-methane. Feasibility of an international value chain is being studied in a variety of regions. In particular, with regard to e-methane, demonstration projects are progressing in several regions around the world as well as feasibility studies of cross-border value chain of e-methane. Ideally, e-methane production sites should be located to secure abundant and inexpensive hydrogen and CO₂ as feedstocks, besides close to natural gas transmission pipelines, liquefaction facilities, and easily accessible to LNG exporting terminals. In order to stimulate investment in commercialization, development of internationally applicable GHG accounting rules is need at first. It is essential that the CO₂ emitted in combustion is recognized under international accounting rules as having environmental value attribute that does not increase CO₂ in the atmosphere. As one of the examples, the Japan Gas Association and related organizations have developed a certification scheme called "Clean Gas Certificate" and has applied it to several domestic e-methane production projects in Japan. For the transition period (2030-2050), the use of recycled CO₂ captured from factories and thermal power plants emissions are expected to be major feedstock. We propose GHG calculation and accounting method in consideration of avoiding double counting of recycled CO₂ in the entire supply chain. A calculation formula of the carbon footprint (CFP) of e-methane was proposed to one of the ISO's working groups and it was successfully included in the ISO 6338-1:2024. Next, it is necessary to harmonize the proposed methods with internationally common GHG accounting rules.

KEYWORDS: e-methane, methanation, carbon capture utilization, GHG accounting rules, GHG intensity, recycled carbon fuels, environmental attribute certificates, Clean Gas Certificate

1. Introduction

Many countries and industries in the world are aiming to transition to a carbon neutral society. One of the means to achieve this is the use of recycled carbon fuels (RCFs) such as e-methane. In [1], our previous paper "Promoting Introduction of E-methane for Carbon Neutral City Gas Supply in Japan", focused on e-methane and overviewed about the gas industry's challenge of technological development and related initiatives such as net GHG emission calculation of e-methane. Following it, this paper describes the progress of the challenges of technological development, demonstrations, and feasibility studies for

commercialization. The core concept is CO₂ capture and utilization (CCU) which enables carbon reduction. As an example, by use of e-methane, Figure 1 shows an image of the principle of RCFs. By replacing fossil fuels with RCFs, CO₂ emissions can be reduced.

In order to stimulate investment in commercialization, development of internationally applicable GHG calculation and accounting rules is essential. The originality of this paper is that it makes a proposal based on the authors' practices, while taking into account existing international standards to address this issue. This paper also introduces a certification scheme which has

developed to enable transferring the environmental value attributes of RCFs such as e-methane.

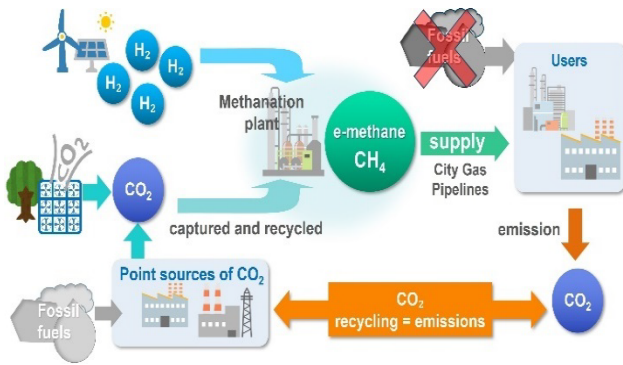


Figure 1: Image of methanation process for carbon neutral city gas supply

2. Expectations for e-methane and initiatives to date

In [2], the IPCC's 6th Assessment Report, released in April 2022, states "For greater compatibility with existing gas systems and appliances, the hydrogen can be combined with captured carbon dioxide to form methane and other synthetic fuels". In [3], a model analysis of IEA's "Net Zero by 2050" also estimates that 35% of global gas demand supplied by the gas grid in 2050 will be supplied by low-carbon gases, of which about 30% will be e-methane.

In September 2024, the IEA held a webinar focusing on e-methane for the first time, and in [4], Molnar presented survey looking over the global situation. Leading projects taken up by the IEA are shown in Figure 2. Among them, Tree Energy Solutions (TES) and Nordic Ren-Gas as well as the Japan Gas Association were invited as panelists and presented leading projects.

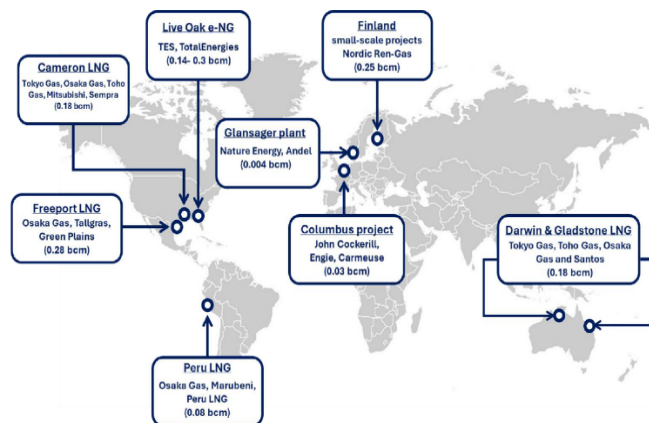


Figure 2: International partnerships drive e-methane projects (IEA's webinar on E-methane: a new gas for a net-zero future?)

In [5], Vercamen announced the formation of the e-NG Coalition, a framework for large companies to collaborate and advocate for their portfolio of e-methane projects in Japan, North America, Europe, and the Middle East.

In [6], Kujara, Nordic Ren Gas presented its plans of commercial production of e-methane at six sites in Finland to be operated from 2027, and announced that one of their

project was selected by the EU Hydrogen Auction bid as the most competitive cost of hydrogen.

In [7], the Japan Gas Association presented about its Action Plan in June 2021, which sets an interim goal for the entire city gas industry to establish a value chain including overseas imports of e-methane covering 1% in city gas supply (approximately 400 million m³) in 2030. And this includes a goal by 2050 of achieving carbon neutral city gas supply by e-methane as main feedstock (Figure 3).

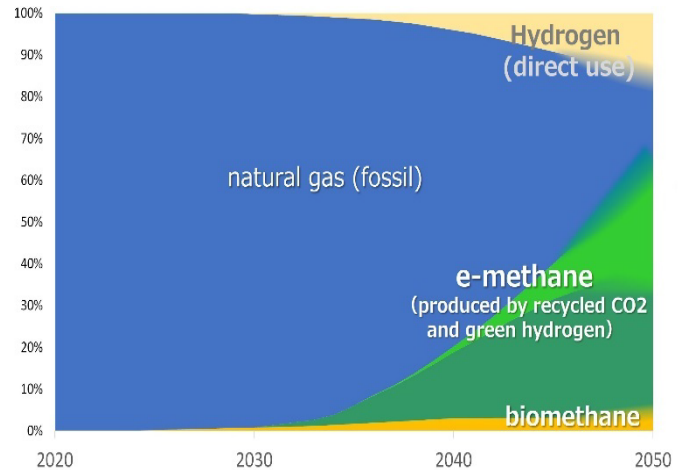


Figure 3: JGA's vision of transition of the share of feedstocks for Japan's city gas supply

In [8], European Biogas Association (EBA) published an Europe-wide study in September 2024. It reports a comprehensive survey on the e-methane projects in Europe. Figure 4 shows the increasing trend in number of e-methane production plants by country.

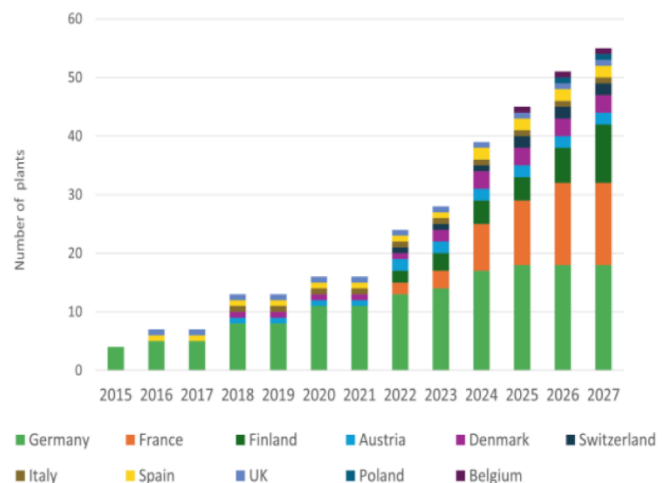


Figure 4: Growth in number of e-methane production plants in Europe (EBA; Mapping e-methane plants and technologies, 2024.9)

References above are appropriate to representing the latest situation. All of them suggest importance of proving the origin of the feedstock CO₂, but most of them are limited within biogenic CO₂, and there is few information of eligibility of fossil fuel-originated CO₂. Therefore, the attribution of emissions of fossil-originated CO₂ that is captured and used as feedstock are not discussed enough.

3. Harmonizing Internationally Applicable GHG Calculation and Accounting Rules for RCFs

3.1. Need for rules for cross-border transported RCFs

Ideally, the e-methane production site should have access to abundant and inexpensive hydrogen and CO₂ as feedstock and easy access to natural gas transmission pipelines, liquefaction, and LNG transportation. Several feasibility studies are currently underway in many countries and regions, including North America, Australia, Southeast Asia, Middle East, and South America. Figure 5 shows various feasibility studies (FSs) led by Japanese companies.

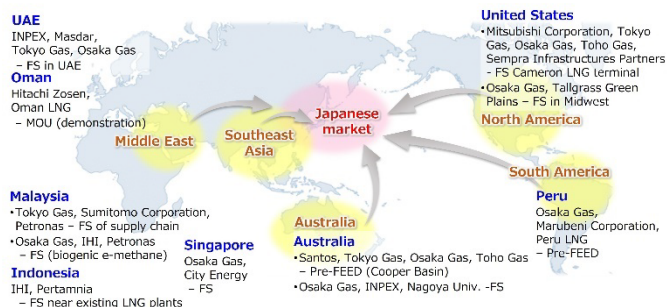


Figure 5: Various feasibility studies led by Japanese companies

As a result of site evaluations and feasibility studies conducted in various locations, they selected the area around the existing LNG export terminals as the most promising area because of their existing infrastructures for stable procurement of raw materials enabling early establishment of a value chain for e-methane. Some are expected for investment decisions. However, there is still no common international rule that can certify GHG calculation covering entire cross-border value chains and the transfer of environmental values of RCFs such as e-methane. Without them, there is concern that investment decisions would be delayed.

3.2. Existing international general rules for GHG calculation and accounting

During the transition period (from around 2030 to 2050), CO₂ captured from point sources is expected to become the major feedstock for producing e-methane. If the CO₂ emitted from point sources such as factories and power plants has already been accounted for and reported by the emitters, since the CO₂ would have been released into the atmosphere, when the e-methane is combusted, regardless of its origin (e.g. fossil or non-fossil), the emitted CO₂ should not be counted as additional emission in order to avoid double counting. This means that recycled carbon fuels (RCFs) such as e-methane have environmental value contributing CO₂ emission reduction, as stated in the 6th IPCC assessment report [2].

In order to promote social implementation of e-methane, common calculation method is needed to estimate the amount of CO₂ reductions by substituting

fossil fuels. Internationally accepted rules for calculating GHG emissions include the IPCC Inventory Guidelines at the national level, the GHG Protocol Standards and Guidelines and ISO 14064, ISO 14067 (carbon footprint) at the corporate and product level. Method to calculate environmental value of RCFs such as e-methane should be harmonized with these existing rules.

One of the representing analysis of GHG emission of RCFs covering entire supply chain is by S. Morimoto et. al.. In [9], Morimoto calculated lifecycle GHG emission of e-methane imported from abroad to be 0.95-1.65 kg-CO₂/kg-CH₄ (nearly equals to 17.0-29.6 g-CO₂/MJ) under a condition that hydrogen is produced by renewable power.

Another example is that specific default values are being set for over 100 fuel types, including RCFs, which are being discussed at the International Maritime Organization (IMO). In [10], when the CO₂ is derived from the point sources such as flue gas after combustion of fossil fuels, calculation formulas are provided to subtract the amount of CO₂ emitted during combustion from the amount already reported by the original emitter. The calculation method accumulates the CO₂ emitted throughout the supply chain.

3.3. Development of calculation formula of GHG intensity in ISO

Based on the standards and guidelines mentioned above, we proposed a calculation formula to one of the ISO's Working Group. As shown in Figure 6, referring ISO 14067, the proposed formula is to reflect in carbon footprint of e-methane within the entire boundary of well to consumption (WtC) in consideration of the environmental value that it does not increase CO₂ in the atmosphere if the CO₂ feedstock meets certain criteria.

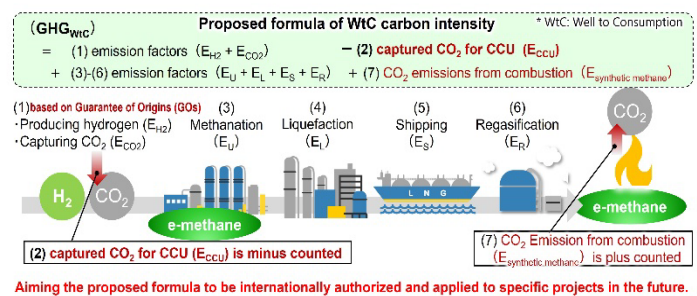


Figure 6: Proposed calculation formula of GHG intensity of e-methane

If the CO₂ feedstock is obtained by direct air capture (DAC) or biogenic origin, or if the CO₂ is already reported as GHG emissions before the e-methane production process, the captured CO₂ can be minus counted. This can offset the CO₂ emitted from combustion of the e-methane. In [11], this formula has been included in the ISO 6338-1:2024 (Calculations of greenhouse gas (GHG) emissions throughout the liquefied natural gas (LNG) chain Part 1: General) in January 2024.

This method was referenced when determining the upper limit of GHG emissions intensity of 49.3 g-CO₂/MJ, which is recognized as “low-carbon hydrogen, etc.” as stipulated in [12] “Basic Act on a Hydrogen Society”, it has been enacted by the Japanese government in May 2024.

3.4. Need for common rules to clarify the attribution of environmental value of RCFs

The next issue to be resolved is to develop common rule regarding who own the environmental value of e-methane, which does not increase atmospheric CO₂ even when combusted. In the case of biofuels, it can be commonly accepted that those who paid cost for biofuel own the environmental value. Recently, there is also a system in which the ownership of the environmental value is transferred by issuing certificates that separate the environmental value from the biofuels.

In the case of RCFs, unlike biofuels, the process of procuring CO₂ feedstocks and artificially synthesizing them is included in the value chain from production to consumption. The difference from biofuels and lack of common rules for RCFs causes uncertainty of the reward to the investment to developing a value chain for RCFs such as e-methane.

In Japan, discussions on how to handle CCU including e-methane are progressing. One of the most progressed discussions held in Japan was the Public-Private Council for Promoting Methanation led by the Ministry of Economy, Trade and Industry in 2021, and the Task Force for CO₂ Counting Rule under its auspices, have been held to discuss on this issue intensively.

In [13], the interim report issued by Ministry of Economy, Trade and Industry in 2022, as shown in Table 1, four cases, in which merits and demerits are included for the original emitters (captures’ side) or the final users, or both, depending on account for emissions or not.

Table 1: Examples of CO₂ accounting among stakeholders by cases [13]

		Original emitter (capturers’ side)	Users’-side
CO ₂ behavior related to e-methane production and utilization			
		Factories, Utilities	E-methane users
CO ₂ accounting for domestic production and consumption	Case 1	Account for emissions	No Emission
	Case 2	No emission	Account for emissions
	Case 3	Allocating emissions	Allocating emissions
	Case 4	No emission	No emissions

This report concluded that unless the environmental value is attributed to the users’ side, e-methane will not be selected. Therefore, it was proposed that the users’ side should account for as no emission. On the other hand, it suggested that complementary mechanism was necessary because there was a risk that production and supply of e-methane would not take place unless sufficient incentives

were provided to those who capture CO₂ rather than emitting it to the atmosphere.

There is a progress to create a system in which the original emitters (capturers’ side) can also claim environmental value for themselves, depending on the final use, by requiring proof of the captured CO₂ for CCU and proof of the final use.

Issues relating internationally applicable accounting rules has been raised in the intergovernmental frameworks. One of the examples is the Group of Seven (G7) Energy and Environment Ministerial Meeting held in Sapporo in April 2023. In [14], the communique stated that member countries would work together to resolve the issue (GHG accounting for RCFs).

As of now, the IPCC Inventory Guidelines nor the GHG Protocol, both are the most representative international rules, have not include any provisions regarding the treatment of CCU. As a result, even if RCFs is procured and used, users would not be rewarded since the CO₂ emitted during combustion still needs to be accounted for. As announced in [15] and [16], it is expected that discussions on CCU-related issues including RCFs will start from 2024 or 2025 and will be completed in a few years.

Meanwhile, as announced in [17], the EU’s Renewable Energy Directive (RED) Delegated Act, which is a common rule for all member countries, came into effect in June 2023. It stipulates the calculation method for the environmental value of RCFs and RFNBOs (liquid or gaseous renewable fuels of non-biological origin). It would be possible that this will not only have an impact within EU, but also spread to the rest of the worlds.

4. Development of Environmental Attribute Certificates for e-methane

From around 2023, discussions have emerged on internationally applicable counting rules that clarify the attribution of environmental value for RCFs including e-methane and the direction is to contribute to motivate developing value chain for RCFs including e-methane.

In certain regions, certification schemes for RCFs are almost being finalized.

4.1. Voluntary Scheme recognized by European Commission

In [18], the European Commission has announced that several existing international voluntary schemes have completed the positive technical assessment (September 2024) to be recognized as institutions responsible for third-party review in line with the Delegated Act [17]. For example, in [19], ISCC (International Sustainable Carbon Certificate) describes requirements for fossil-derived CO₂ to be eligible as feedstock for RCFs and RFNBOs as follows; “Post-industrial (fossil) CO₂ captured from

industrial processes, which use fossil sources to deliberately produce electricity, heat, or materials (e.g., cement, iron and steel, petrochemical industry) must be verified that the CO₂ was not deliberately produced for use in the above-mentioned production processes.”

4.2. Clean Gas Certificate (Japan)

(1) Overview of Clean Gas Certificate

We developed and launched “Clean Gas Certificate” scheme with gas-related organizations in Japan that certifies the attribution of the environmental value of e-methane and biogas, which is considered as not increasing CO₂ in the atmosphere even when combusted. As shown in Figure 7, this is environmental attribute certificate (EAC) making it possible to transfer the environmental value separated from e-methane or biogas and to bundle it with fossil natural gas.

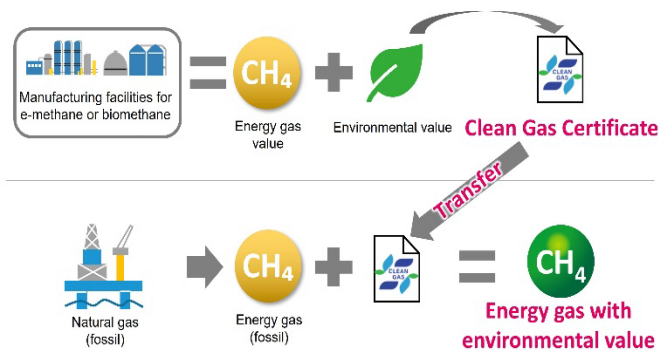


Figure 7: Image of function of “Clean Gas Certificate”

After a trial period in 2023, guidelines were developed, and the system was moved to actual operation as a private certification system from April 2024. In [20], details are posted on the website. With this scheme, e-methane and methane component in biogas are certified based on criteria. An sample image of the certificate to be issued is shown in Figure 8.

The attribute information included in the certificate are listed below. They have been decided based on surveys of some references of foreign certifying and registering systems for renewable fuels such as biogas.

- Serial number
- Issue date
- Production process
- Production period
- Name of the registered production facility
- Hydrogen suppliers' code
- CO₂ feedstock suppliers' code
- Name of the certificate issuer
- Type of clean gas (e-methane / biogas / mixed gas)



Figure 8: Sample image of “Clean Gas Certificate”

- Equivalent amount of clean gas (units: m³ and MJ)
- Use of produced gas (injection into city gas pipelines / private consumption)

(2) Implementation of Clean Gas Certificate

In Japan, various efforts are underway to commercialize e-methane, including technology development, demonstration on both the supply and demand sides, with support from the Japanese government. Figure 9 shows demonstration projects of e-methane production by Japan's major city gas companies.

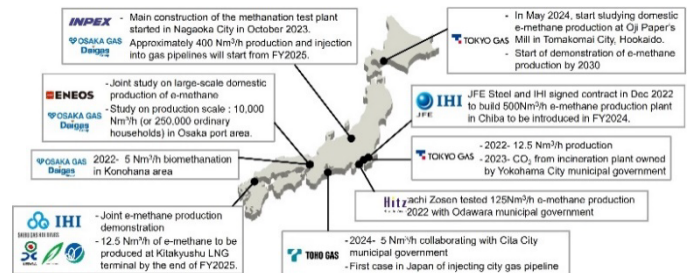


Figure 9: Demonstration projects of e-methane production in Japan

Some of the plants have already certified for Clean gas Certificates as below. Other projects planned in Japan are also expected to apply for the certification.

As announced in [21], in March 2022, Tokyo Gas Co., Ltd. began a methanation demonstration experiment at its research facility in Yokohama. Production capacity is 12.5Nm³/h. It procures electricity from renewable power sources and produce green hydrogen through water electrolysis. Having gained knowledge about the capabilities and issues of water electrolysis and the Sabatier methanation device, it has been working to improve the efficiency of the overall process. And in July 2023, it announced a new initiative to produce e-methane from CO₂ captured from the neighboring waste incineration plant owned by the Yokohama City municipal government, combined with the hydrogen obtained from its on-site water electrolysis device.

As announced in [22], in July 2022, Toho Gas has announced that it would work with the municipal government of Chita City in Aichi Prefecture to conduct a demonstration of methanation using CO₂ captured from biogas generated by sewage sludge treatment of the Chita City Southern Sewage Treatment Center and hydrogen produced by electricity generated from LNG cryogenic power generation. Production capacity is 5Nm³/h. The e-methane has been injected to the city gas supply network, which is for the first time in Japan.

As announced in [23], in December 2023, Saibu Gas announced that it started a demonstration project for methanation in Kitakyushu City in Fukuoka Prefecture using local raw materials in collaboration with nine other entities. Production is planned in FY2025 and with the capacity of 12.5Nm³/h. City gas customers, academia are

working together. Other city gas companies such as Hokkaido Gas, Hiroshima Gas, and Nihon Gas as well as the JGA also joined in this project aiming to transplant this model to other city gas supply areas.

As announced in [24], INPEX and Osaka Gas announced the start of a joint technology development project for the practical application of a methanation system. E-methane will be produced from FY2025 using CO₂ extracted from INPEX's gas field in Nagaoka City in Niigata Prefecture and will be injected into the company's existing gas pipeline. The e-methane production capacity is planned to be about 400 Nm³/h.

As one of the representative examples of its users, as announced in [25], Osaka Gas has been assigned to supply Clean Gas Certificate bundled city gas to the facilities located in the EXPO 2025 Osaka, Kansai during the period of the event.

4.3. Aiming for broader internationally applicable schemes

Broader than above cases, it is necessary to operate the scheme based on internationally applicable CCU-related accounting rules to be developed in the near future. It is necessary to build in on the existing LNG supply chain that include tracking information on the guarantee of origins (GOs) of the feedstocks, CO₂ and H₂, and the GHG intensity of e-methane shown in Figure 6. Figure 10 shows an image of e-methane certificates in circulation.

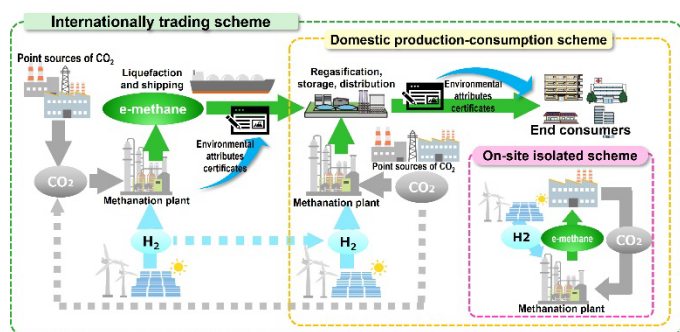


Figure 10: Image of environmental value transfer schemes in the existing LNG value chain including environmental attributes certificates

There are some notable developments regarding the IPCC Inventory Guidelines and GHG Protocol, which are the most commonly referenced GHG calculation and accounting rules in the world.

The IPCC has announced that it will hold expert meetings focusing on CO₂ removal and CCUS in the IPCC's Inventory Task Force through 2027, and will revise the inventory guidelines. As announced in [26], At the expert meeting in July 2024, “Address potential double-counting from the use of synthetic fuels (e.g. efuels)double counting” was raised as one of the issues to be considered.

The GHG Protocol is due for a major revision by the second half of 2026. In order to propose the addition of new rules on CCU to the standards and guidance, in [27], we submitted a proposal (open letter) to the secretariat in

January 2024, signed by 18 voluntary organizations. As published in [28], we also appealed for the need for rules related to CCU at a session attended by the representative of the GHG Protocol Secretariat at the annual general meeting hosted by a European organization that promotes CCU, and he responded positively to our appeal.

Since diverse stakeholders intervene, a platform is needed to manage the history of GHG emissions tracking, verification, and transfer of the value of reduction credits at stages along the value chain. For example, as announced in [29], Osaka Gas Co., Ltd., Mitsubishi Heavy Industries, Ltd. and IBM Japan, Ltd. are jointly conducting a proof-of-concept (PoC) of a system to visualize CO₂ emissions throughout the supply chain and the environmental value of e-methane (Figure 11). It is expected that such fundamental technology will be developed at an early stage to serve as a platform for tracking, verifying, and managing the transfer of environmental values.

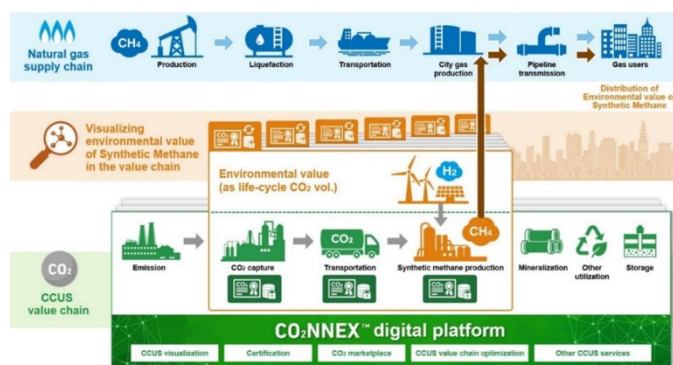


Figure 11: Example of digital platform tracking GHGs in e-methane supply chain

We will continue to monitor future discussions and work to harmonize our schemes with their revisions.

5. Conclusions

This paper focuses on e-methane, which is a leading RCFs produced from hydrogen derived from renewable energy and recycled CO₂, and which is attracting particular attention in Japan, Europe and North America because it can make the most of the existing LNG value chain. By leveraging the advantages of drop-in fuels, it is possible to reduce social costs and contribute to a smooth transition to a carbon-neutral society.

In this paper, we strongly advocate the need for international common rules for GHG calculation and accounting for RCFs through cross-border supply chains, which is a common issue for the social implementation of RCFs. In the early stages, the value chain of RCFs, including e-methane, is expected to grow within regional economic blocs such as Japan, EU and APEC, and in specific industries such as international shipping. As a result of certification of GHG intensity and in the carbon pricing system, market prices will be formed for RCFs. Based on the above circumstance, as a first step, we have

standardized the GHG intensity calculation formula for e-methane at the ISO and have also started to operate the Clean Gas Certificate scheme, which certifies the environmental value of e-methane produced at demonstration plants in Japan. Through these initiatives, we believe that the knowledge of trade-offs between GHG intensity and cost will contribute to form global RCFs market.

We especially expect academic world to scientifically clarify trade-off relationships that are more versatile. By sharing this knowledge, industrial sector is expected to work towards the formation of a global RCFs value chain. Everyone should collaborate to establish appropriate rules for a smooth transition to a carbon neutral society.

Conflict of Interest

The authors declare no conflict of interest.

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