Essays on the Carbon Sources of Carbon-Recycle Fuels (1)
— Addressing Misconceptions of Methanation such as CO_2 Re-emission, and Long-term Perspectives —

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Carbon-recycle fuels (synthetic fuels)[1] are hydrocarbon fuels synthesized from hydrogen and carbon dioxide, and there are high expectations of the role they can play toward the realization of a decarbonized society. However, as they straddle the two technological fields of hydrogen and CCU (and carbon recycling), this often gives rise to misconception and confusion about their decarbonization effect and significance. In light of that, this series of articles examines the principles and long-term approach for carbon-recycle fuels, and the attribution of CO_2 emission reduction effect, with the aim of contributing to the development of materials for future discussions on energy policy. The first paper looks at the case of carbon-neutral methane (CN methane) and explains its principles, while suggesting the possible challenges toward the achievement of a decarbonized society in 2050. The second paper discusses the selection of CO_2 sources in the decarbonized society of 2050 as well as the transitionary period leading up to 2050. The third paper develops a wide range of approaches with regard to the attribution of CO_2 emission reduction effect when using recycled carbon fuels.

1. Key points of this paper

- While there are high expectations of the role that hydrogen and carbon-neutral methane (CN methane) can play in the decarbonization of city gas, there are still misconceptions about CN methane. There is first a need to reaffirm the principles, functions, and roles of methanation (production of CN methane). Based on the correct understanding of these points, there is then a need to set out an outlook for the approach for CN methane in the decarbonized society of 2050 as well as the transitionary period leading up to 2050.
- CN methane is synthesized from CO_2 that is separated and captured from certain facilities, and hydrogen that is sufficiently decarbonized. As the CO_2 that is emitted through the use (combustion) of CN methane is offset (cancelled out) with the separated and captured CO_2, the substitution of natural gas through the use of CN methane produces a CO_2 reduction effect. In short, as CO_2 is only separated and captured, utilized, and re-emitted, the use of CN methane is essentially the same as use of hydrogen. Accordingly, based on the principles, CO_2 emissions from CN methane are not problematic.
- There are forms of CCU and carbon recycling that contribute to reducing CO_2, and those that do not. Although CO_2 is used and recycled in the CCU-related processes of synthetic fuel production and utilization, including methanation, the objective is to make hydrogen easier to be used and not to generate CO_2 emission reduction effect. CO_2 emission reduction effect is ultimately generated through the hydrogen.
- Misconceptions about CO_2 re-emissions from CN methane and the CO_2 emission reduction effect are probably the result of focusing solely on CO_2 behavior by classifying methanation in the field of CCU. As the effects of CN methane are dependent on hydrogen, it would be appropriate to

[1] As there are no fixed names or terms, what is referred to as "recycled carbon fuels" in this series may—depending on the situation—also be known as synthetic fuels, or as carbon-neutral methane for methane produced through methanation.

categorize methanation under the field of hydrogen rather than CCU, in order to avoid such misconception.

2. Body text

Introduction

There are high expectations of the role that hydrogen and synthetic methane (carbon-neutral methane, or CN methane) can play in decarbonizing city gas, and we face the important question of how to produce, transport, and utilize these gases in an economically efficient way. However, the significance of CN methane is still often misunderstood. In particular, it is claimed that CN methane re-emits CO_2 during combustion, and therefore makes it necessary to capture that CO_2 once again, or to offset it. While this can be considered as an interpretation that is conscious of the recent goal of realizing a decarbonized economy by 2050, it is also believed to be the result of misconceptions of the very principles of methanation.

In any case, many of the misconceptions are probably the result of focusing solely on the behavior of CO_2 by classifying methanation in the field of CCU. There is first a need to reaffirm the principles, functions, and roles of methanation. If the challenges toward the achievement of a decarbonized economy by 2050 are not clarified based on an accurate understanding of these aspects, the positioning of methanation in the important transitionary period toward the realization of a decarbonized society in 2050 may become ambiguous. Accordingly, this paper reaffirms the principles of methanation, then organizes the long-term issues and sets out an outlook for the approach for hydrogen and CN methane.

CN methane ≒ Hydrogen, methanation ∉ CCU

Firstly, we shall reaffirm the principles of CN methane separately from the goal of achieving a decarbonized economy in 2050. The mechanism behind CN methane is as follows: it is produced (methanation) through the synthesis of CO_2 with sufficiently decarbonized hydrogen, CO_2 is emitted in combustion during utilization, and conventional natural gas is substituted in that process. In short, CO_2 that is separated and captured from certain facilities is offset (cancelled out) by CO_2 that is emitted through the combustion of CN methane, while CO_2 is reduced through the substitution of natural gas that would have been used if CN methane were not utilized (however, the effect is diminished for CO_2 emitted from CO_2 separation and capture and the CN methane production process). In other words, the utilization of CN methane is the same as the direct utilization of sufficiently decarbonized hydrogen, and the utilization of CN methane is essentially equivalent to “the utilization of hydrogen” and “the substitution of natural gas by hydrogen” (a comparison of the cases in the left and center of Figure 1 shows that CO_2 emissions volume for the overall system is the same). On the other hand, if we were to focus on “the utilization of hydrogen,” CO_2 separation and capture is neither related to, nor exists in, that process. Accordingly, it would be appropriate to classify methanation (production of CN methane) in the field of hydrogen, and not in the field of CCU. An argument that we have heard of from long before is, as CN methane re-emits CO_2 during combustion, it is necessary to capture that CO_2 once again, or to offset it. This is a misconception that has arisen from focusing solely on the re-emission of CO_2 by classifying methanation in the field of CCU (and carbon recycling). Incidentally, IEA uses the term “hydrogen-based fuel” for synthetic fuel. Hypothetically, even if methanation were classified under CCU, CO_2 is only separated and captured, utilized, and re-emitted; no CO_2 emission reduction effect is generated through its function as CCU. The CO_2 emission reduction effect generated through CN methane is dependent only on hydrogen.

The following question arises: why do we go to the trouble of producing CN methane by synthesizing hydrogen with CO_2, instead of just utilizing hydrogen as it is? This is because hydrogen, in the form of CN methane, is easier to use in existing city gas infrastructure. Blending hydrogen as it is into the city gas infrastructure (although this is also dependent on the volume of hydrogen) creates challenges such as the need to change the regulations, adjust or change the equipment, and change the measuring method, but the blend of CN methane, which is the main feedstock of city gas, is said to make it possible to avoid many of these challenges. The new fuel derived from hydrogen, which can be used as it is in existing infrastructure, is also called "drop-in" fuel. In short, methanation is ultimately one of the ways of utilizing hydrogen in city gas that takes into consideration economic rationality based on the effective use of existing city gas infrastructure, as well as the second best measure. In other words, we can say that if there are cases where it is possible, from the perspective of economic rationality, to directly utilize hydrogen through hydrogen blends or new hydrogen infrastructure, it would be better to apply such methods; methanation itself must not be the objective. It is important to carry out verification continuously to assess if hydrogen or CN methane is the more economical decarbonization option, while taking into consideration factors such as the city gas demand structure for each region and the period for the renewal of city gas infrastructure.

Sources of CO_2 for methanation

Based on the above clarification of the principles, CO_2 reduction effect through natural gas substitution (in the case where the difference caused by the efficiency of the process is disregarded) is the same regardless of whether the CO_2 that is used in methanation is derived from fossil fuels, biomass, or DAC (a comparison of the cases in the right and center of Figure 1 shows that CO_2 emissions volume for the overall system is the same). Of course, emissions are not negative when it is derived from biomass and DAC.

Figure 2 compares the cases where CO_2 from fossil fuels and CO_2 from DAC is used in methanation. CO_2 from thermal power plants is diffused in the atmosphere, in any case. The separation and capture of CO_2 before it is diffused, is the same as utilizing direct air capture (DAC) to separate and capture CO_2 from the atmosphere. In short, CO_2 that is used in methanation is the same regardless of whether it is derived from fossil fuels or DAC. In other words, if there exist thermal power plants, it would not be problematic to use the CO_2 from these plants, but it would not do to construct or maintain thermal power plants deliberately for the sole purpose of methanation.

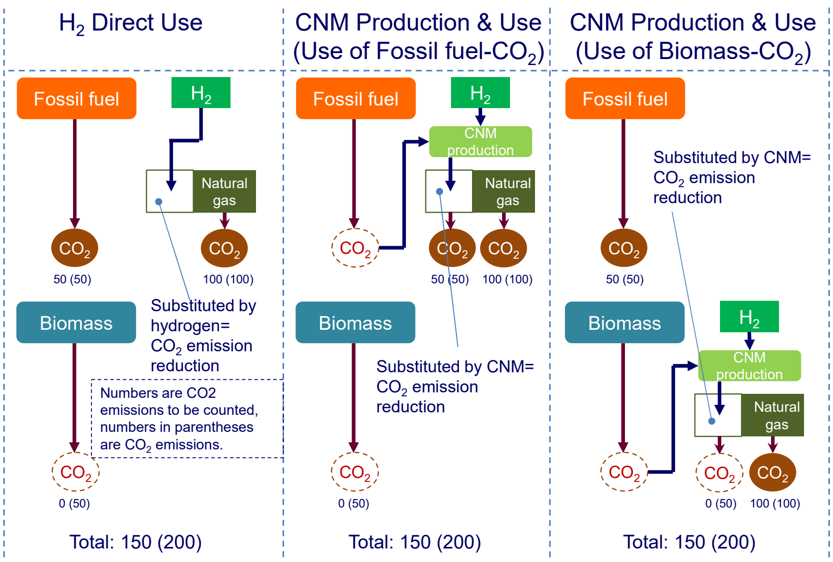

Figure 1　CO_2 emission reduction effect is the same in the utilization of hydrogen and the utilization of CN methane

Note: "CNM" refers to CN methane.

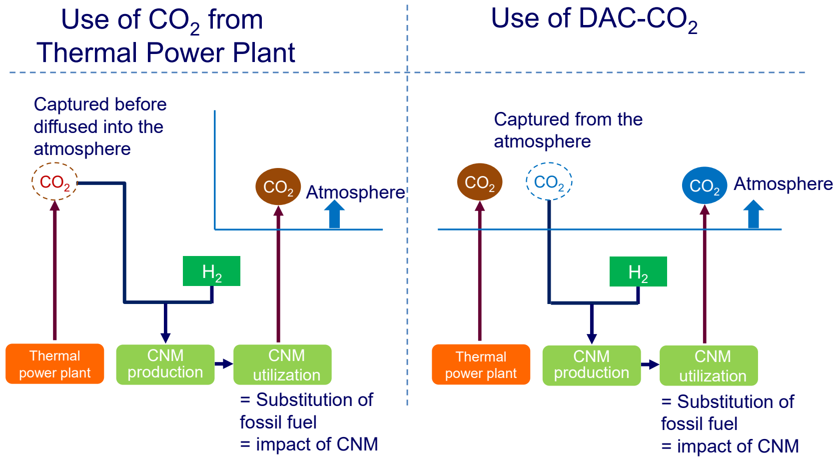

Figure 2 CO_2 in CN methane production and utilization is the same regardless of whether the CO_2 is derived from fossil fuels or DAC

Note: "CNM" refers to CN methane.

In Europe, it is argued that the CO_2 used for methanation has to be derived either from biomass or DAC. However, this would be wrong based on a scientific interpretation of the principles of methanation. We can infer that political factor lies behind this, such as the intent to avoid extending the use of fossil fuels. As Europe has a history of restricting the use of fossil fuels, this argument is as a result no more than an indication of the argument that synthetic fuel manufacturing processes, including methanation that uses CO_2 derived from fossil fuels, are not allowed; it does not capture the essence of synthetic fuels.

Hence, based on the principles, if the hydrogen has been sufficiently decarbonized, CO_2 re-emission from CN methane is not problematic, and it does not matter what the source of the CO_2 is. However, as Japan aims to become a decarbonized economy by 2050, we may be approaching a turning point with regard to the interpretation of CO_2 sources. In 2050, when CO_2 emissions from fossil fuels are likely to be extremely limited, and in the transitionary period until then, how the synthetic fuels should be, including CN methane? This shall be discussed in the second paper.

References

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