Essays on the Carbon Sources of Carbon-Recycle Fuels (4)
—Concluding the Series of Essays—

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Concluding the series of essays

In this series of "Essays on the Carbon Sources of Carbon-Recycle Fuels" (1)–(3), the first paper introduced the principles of carbon-recycle fuels, the second paper looked at the points to note in building a decarbonized economy by 2050, and the third paper examined various schools of thought on the attribution of CO_2 emission reduction effect. The following is the clarification of the key points in this series of essays. We hope that this series contributes to the formulation of policies and design of systems related to carbon-recycle fuels, with a view to the realization of a decarbonized economy by 2050.

- Carbon-recycle fuels are synthesized from sufficiently decarbonized hydrogen and CO_2. In addition to the need for hydrogen, it is accompanied by CO_2 separation and capture in the fuel production process and CO_2 emissions in the fuel utilization process (combustion). As such, the evaluation of CO_2 emission reduction effect and schools of thought on the attribution of the effect are extremely complex.
- Based on the principles, since the effect of carbon-recycle fuels is derived from hydrogen, under the condition of sufficient decarbonization of hydrogen, the selection of CO_2 sources and CO_2 re-emission would not be problematic. However, a different perspective is required if the objective were to establish a decarbonized economy. In the transitionary period until the realization of a decarbonized economy in 2050, the utilization of CO_2 derived from fossil fuels from the thermal power generation and industrial sectors is conceivable. On the other hand, in the case where the establishment of a decarbonized economy in 2050 is the condition, the re-emission of CO_2 must be avoided. In other words, at a point where carbon constraints are relatively lax (such as 2030 or 2040), fossil fuel-derived CO_2 could possibly hold the key to the expansion of carbon-recycle fuels. On the other hand, we cannot deny the possibility that constraints to the reuse of fossil fuel-derived CO_2 may arise by 2050, making it necessary to shift to carbon sources such as CO_2 derived from biomass or direct air capture (DAC). It is important to have a CO_2 procurement strategy that takes the time axis into consideration.
- There are now ongoing discussions about carbon pricing and the decarbonized economy of 2050 in Japan, and these could have an impact on the approach to carbon sources. For example, if carbon taxes were strengthened, taxes may be imposed on systems that reuse fossil fuel-derived CO_2. Furthermore, in the realization of net zero emissions in 2050, if fossil fuel-derived CO_2 were reused, there would be a need to offset the positive emissions. Who would shoulder the carbon taxes and the offsetting costs, the carbon providers, or the users? This would become an issue. It is also closely related to the problem of the attribution of CO_2 emission reduction effect elaborated below. As shown in the estimates drawn up in the second paper, it is important to consider the costs when discussing the feasibility of using fossil fuel-derived CO_2.
- The interpretation of the attribution of CO_2 emission reduction effect in the production and utilization of carbon-recycle fuels is an extremely complicated matter. Based on the principles, CO_2 in the production and utilization of carbon-recycle fuels is merely separated, captured, and re-emitted, unlike in the case of CCS where CO_2 is sequestrated and stored semi-permanently. In

the process of the former, no CO_2 emission reduction effect is generated, and the CO_2 emission reduction effect depends solely on hydrogen. As such, all of the CO_2 emission reduction effects are considered to be attributed to the users of carbon-recycle fuels (in other words, the users of hydrogen). On the other hand, as carbon-recycle fuels cannot be produced without the provision of CO_2, CO_2 providers and the producers and users of carbon-recycle fuels share an interdependent relationship. For this reason, there is also a school of thought that posits that CO_2 emission reduction effect should be allocated to both parties. In other words, for example, while fossil fuel users are also sources of CO_2 emissions, they are also the providers of CO_2 that are necessary for the production of carbon-recycle fuels. In this sense, there is a need for fossil fuel users and the producers and users of carbon-recycle fuels to cooperate and work together.

- Carbon-recycle fuels are a means for facilitating the use of hydrogen in an economically efficient manner, through the utilization of mature, existing technologies and infrastructure that are now the foundation for fossil fuels. There is a need to pay attention to the fact that reducing CO_2 emissions through CCU and carbon recycling is not the primary objective. However, as they straddle the technological fields of hydrogen and CCU/carbon recycling, this complicates the interpretation of their functions and roles. In order to position carbon-recycle fuels as one of the options for the realization of an economically rational decarbonized economy, there is a need to further deepen discussions on the concrete system design, with a view to early social implementation.
- Unlike the easy-to-understand CCS technology of avoiding the discharge of CO_2 into the atmosphere semi-permanently through sequestration and storage, CCU and carbon recycling encompass a wide range of technologies. These include carbon-recycle fuels addressed in this paper, which require hydrogen and for which hydrogen plays a key role in reducing CO_2, technologies similar to CCS in which carbon sequestration has mostly been achieved, such as calcium carbonate and concrete curing, and technologies that already make use of CO_2 derived from fossil fuels, such as urea, methanol and dry ice. While the concept of CO_2 recycling is an important one, there is a need to classify the functions and effects of each type of technology in detail, such as whether CO_2 is sequestrated and discharge into the atmosphere can be prevented, or whether it brings about CO_2 emission reduction by substituting one thing for another. Without this thought and classification process, the misconception that all CCU and carbon recycling technologies contribute to decarbonization may be planted. At the same time, there is also a possibility that all technologies may be positioned as meaningless efforts toward decarbonization.

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