Management of CO2 in the Atmosphere and Ocean Using Solid Earth

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Global warming arising from CO2 emission causes various threats to global environments, including sea level rising. To reduce such environmental changes or related disasters, we need to reduce emission of greenhouse gas, such as CO2. After industrial evolution, we continue to extract hydrocarbon from the earth interior, and CO2 concentration in the atmosphere is increasing at the rate that we have never experienced. In order to mitigate the rapid CO2 increase, several technologies for CO2 reduction have been proposed. When we evaluate CO2 reduction technologies, we should consider the following three parameters; (1) amount of CO2 reduction, (2) time to achieve CO2 reduction and (3) cost for CO2 reduction. For example, wind and solar powers are attractive energy, however it is difficult to store the electricity derived from such time-variant renewable energy. The hydrogen is attractive material to store energy. If we produce the hydrogen from the excess energy derived from solar and wind powers, we can achieve carbon-neutral society. However, present technologies for conversion from excess electricity to hydrogen are still expensive, and we will need time to develop the technology fo the conversion.

By considering these 3 factors (amount, time and cost) described above, CO_2 reduction using the earth could be one of realistic approaches. As CO2 reduction approach using the earth, CO2 geological storage (or Carbon Capture and Storage; CCS) that directly injects CO2 into the subsurface reservoir has been recognized. To constrain CO2 emissions to levels consistent with <2°C rise in global temperatures, the International Energy Agency (IEA) demonstrates that CCS needs to contribute ~14% of the cumulative emissions reductions. Furthermore, if we realize negative CO2 emission, CO2 storage using the underground space is a realistic solution. Indeed, large amount of carbon (source of CO2) is originally distributed within the solid earth, and large amount of CO2 generates at volcanoes. Therefore, the CO2 geological storage is similar to natural cycle. The countries close to plate convergent margins, such as Japan and Indonesia, are believed to have limited reservoirs for CO_2 storage. But, previous studies demonstrated that >100 billion tons of CO_2 can be stored around Japanese Island alone, which corresponds to >100 years of the total CO_2 emission from Japan.

Of course, we need to solve several roadblocks in the operation of CO2 geological storage. To reduce large amount of CO2 (14% of the cumulative CO2 emission reduction proposed by IEA), we need to operate several thousand CO2 storage projects in the world. Furthermore, we need to prevent CO2 leakage and fluid injection induced earthquake. Therefore, our group has developed low-cost monitoring system to manage CO2 injection reservoirs in wide area.

Recently, other concepts for CO2 storage have been further proposed. For example, mineralization of stored CO_2 (i.e., calcite precipitation) is generally believed to be a slow process, which would take hundreds to thousands of years in the natural environment. However, it was reported that >95% of the injected CO2 into basaltic rock in Iceland has been transformed to carbonate minerals within 2 years. If CO2 mineralization occurs in a short-term, we could store huge amounts of CO_2 in the stable state that is assimilated to the local geology. In future, we will be able to control CO2 concentration in the atmosphere using the earth.