Toward CO_2 net Zero-emission over Long Term

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1. Historical Significance and Sustainability of Paris Agreement

The Paris Agreement adopted at the 21st Conference of Parties to the United Nations Framework Convention on Climate Change (COP21) in Paris in December 2015 is of historical significance for international response to climate change. For the first time ever, particularly, all countries voluntarily pledged to make efforts tackling climate change and agreed to implement them in a bottom-up stylet. At the same time, long-lasted dichotomy of developed and developing countries (common but differentiated responsibilities) has been transformed to some extent in that emerging economies have agreed to contribute voluntarily to help least developed countries to cope with climate change. Furthermore, the Paris Agreement institutionalized a review every five years, clarifying a way in which greenhouse gas emission reduction targets would be toughened over a medium to long term.

On the other hand, UNFCC parties agreed to limit a temperature increase since pre-industrialization to well below 2 ℃ (or 1.5 ℃ if possible) over a long term. They also agreed to offset anthropogenic GHG emissions with absorptions (to achieve net zero GHG emissions) in the second half of this century in the context of sustainable development and poverty eradication. These new targets were introduced in a top-down way and went far beyond the traditional target of stabilizing greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system while giving considerations to sustainability and threats to food production, as provided by Article 2 of the United Nations Framework Convention on Climate Change (UNFCCC). This point is discussed later in regard to climate sensitivity.

The problem here is that many studies including those by the UNFCCC and the International Energy Agency (IEA) have pointed out that present pledges would fall far short of accomplishing the 2°C target within this century. Could future efforts allow the bottom-up emission reduction path to cross the top-down path? Could the 2°C target be accomplished? What could be done if the target turns out to be difficult to accomplish?

2. Temperature Rise Limit Target (2°C target) and Climatic Sensitivity

Equilibrium climate sensitivity (ECS) indicates a temperature rise for a case where CO_2 concentrations in the atmosphere are doubled. According to the fifth report by the

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Intergovernmental Panel on Climate Change (IPCC), the ECS ranges from 1.5 to 4.5°C with a probability of 66%. Theoretically, therefore, a temperature rise could go below or above the range. The IPCC report failed to give any best estimate of the climate sensitivity in the absence of consensus among experts.

While economic activities bear a direct relation to CO_2 emissions or concentrations, any relation between concentrations and a temperature rise is uncertain. This means that the concentrations to limit temperature rise at a certain level range wide, or that we cannot set any specific emission reduction target even if a target temperature is fixed. However, an IPCC figure indicates some relation between CO_2 concentrations and a temperature rise. This is because the climate sensitivity is assumed at 3°C. However, there is no scientific ground for endorsing the assumption as right.

Anyway, the IPCC report under the assumption described a CO_2 concentration of 450 ppm as nearly corresponding to the 2°C target. It also indicated that if the climate sensitivity is higher, the temperature rise would be close to 3°C even at the CO_2 concentration of 450 ppm, and that if the sensitivity is lower, the temperature rise would slip below 2 C even at a higher CO_2 concentration of about 680 ppm. In reality, diplomats agreed to set 2°C target based on the assumed climate sensitivity of 3°C. Such negotiations represent decisions based on a vulnerable ground. At the same time as emission reduction measures are implemented, scientific considerations should be conducted to reduce the uncertainties of the climate sensitivity.

3. Feasibility of Accomplishing 2°C Target and Negative CO_2 Emissions

Would it be feasible for the 2°C target to be accomplished if the climate sensitivity is 3°C ? According to the most recent IPCC report, GHG emissions should be close to zero or negative in 2100 in the path for the 2°C target. This means that the target could be accomplished in 2100 if net GHG emissions were reduced to zero. As far as CO_2, the most influential among GHGs, is concerned, however, CO_2 emissions would have to become negative between 2060 and 2080 and minus 10 gigatons or so in 2100 (Fig. 1). (A paper by Rogelj et al. published last year shows that CO_2 emissions would have to become negative between 2045 and 2060 to limit the temperature rise to 1.5°C.) This is because CO_2 stays in the atmosphere far longer than other GHGs. This means that the effects of CO_2 emission reductions take much time to emerge. Could the world realize such level of negative CO_2 emissions in 2100?

Various technologies and measures have been proposed for realizing negative CO_2 emissions. Major ones include the bio-energy with carbon capture and storage (BECCS) to capture CO_2 from bio-fuel for underground storage and CO_2 absorption through large-scale afforestation. As a matter of course, massive land will be required for these measures with adverse effects expected on food production and biodiversity. Relevant costs should also be considered. Papers about such points have begun to emerge in academic journals such as *Nature*. Most of these reports, of which details are omitted here due to space limitations, are negative about these measures. The British government has considered the BECCS system under the Avoid 2 project and indicated a cautious

attitude by pointing out, for example, that farmland amounting to Australia's total area would be required by 2100.

The relationship between costs of achieving the 2 C target and avoided loss thereby (in other word, benefits) is unclear. Given these points, it would be very difficult to achieve massive negative emissions by 2100. Furthermore, there is no specific scientific ground for adopting the 2 C target. Any excessively high target may lose its effectiveness and should be avoided.

4. New Long-term Challenge: Toward net Zero CO_2 Emissions

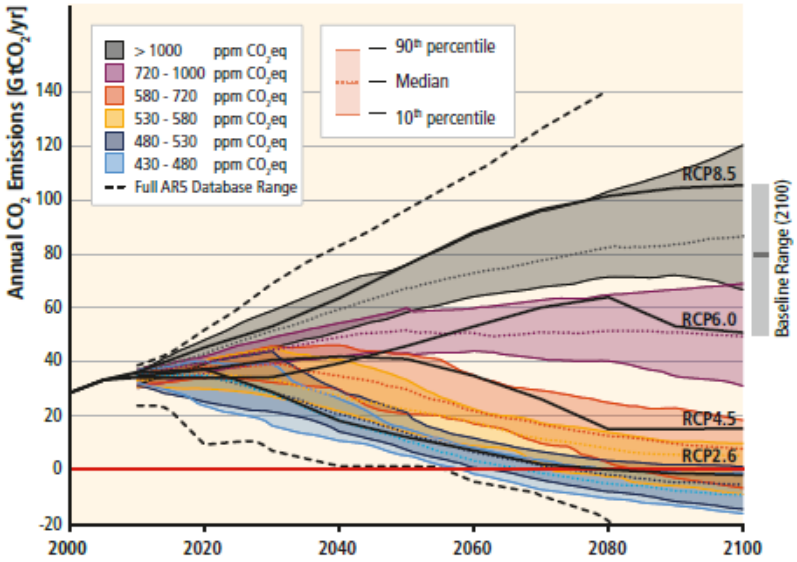
The IPCC report states that cumulative CO_2 emissions have direct relations with a temperature rise due to their long stay in the atmosphere (the relations may change depending on the climate sensitivity). Even if it is difficult to accomplish the 2°C target or net zero GHG emissions (i. e. negative annual CO_2 emissions around 10 giga-tons) by 2100, the world will have to cut CO_2 emissions to zero over a long term to prevent temperatures from continuing to rise. The long-term target of net zero CO_2 emissions may be a new target replacing the 2°C target. The new target represents the elimination of the temperature rise limit of 2°C and the target year of 2100. Negative emissions are not assumed here because they result in massive constraints.

However, the long-term target of reducing net CO_2 emissions to zero is also very challenging. CO_2 emissions from power generation should be zero and will have to depend on renewable energy, nuclear power and fossil fuels accompanied by carbon capture and storage systems. In the transportation sector, ground, maritime and air vehicles will have to be powered by electricity or fuel cells throughout the world, with electricity and hydrogen generation being free from CO_2 emissions. Steel, cement and other sectors that inevitably emit CO_2 will have to fundamentally change manufacturing processes. Given that electricity is required for producing hydrogen, innovative technologies will have to be developed to commercialize space photovoltaics and nuclear fusion power generation. Cities and society in general will have to be innovated to eliminate emissions. The target year for accomplishing the long-term target should be based on global consensus in the context of sustainable economic development.

In this case, temperature rise will exceed 2°C. How far temperatures would rise will depend on the climate sensitivity. In addition to emission reduction measures, risk control measures (including adaptation and geoengineering such as solar radiation management) should be considered.

In response to the Paris Agreement, the IPCC plans to make a special report on the 1.5°C target within 2018. I hope to see a scientific IPCC report considering the feasibility of and conditions and costs for the 1.5°C target accomplishment without sticking to the target itself, irrespective of politics.

Fig. 1　Concentration-based CO_2 Emission Paths
(the lowest path colored in blue deemed to correspond to the 2°C target)



Source: Fig. 6.7, Chapter 6, IPCC/AR5/WG3

Writer's Profile

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Yamaguchi's previous position include Visiting Professor/Project Professor, University of Tokyo (2006–2013) and Professor of Economics, Keio University (1996-2004). Prior to this, he was Senior General Manager at Tokio Marine & Fire Insurance Co., Ltd. He served in numerous positions on committees and councils related Climate change and Environmental issues such as a Lead Author of IPCC Working Group III.