Global Warming and Reduction of Environmental Carbon Dioxide Concentration

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Introduction

These days, global warming is a major concern throughout the world. The cause of the global warming is an increase in greenhouse gases in the atmosphere. Of these greenhouse gases, CO₂, produced by burning of fossil fuels such as coal, petroleum, and natural gas, has become the major factor. In 1992, United Nations Framework Convention on Climate Change (UNFCCC) was established and various countermeasures against global warming were discussed by the signatories. In 1997, COP3 was held at the Kyoto International Conference Hall in Kyoto. At this meeting, the historic Kyoto Protocol was adopted, which set internationally binding emission reduction targets.

At the end of this year, 2015, COP21/CMP11 will be held in Paris, France, the aim of which will be to reach, for the first time, a universal, legally binding agreement that will enable us to effectively combat climate change and accelerate transitions towards resilient, low-carbon societies and economies. Currently, Japan seeks to cut CO₂ emissions in 2020 by 3.8 % from their levels in 2005. The Japanese government announced that in 2013 CO₂ emissions were up 0.8% compared with 2005. (Fig.1 below)

Are You Doing Anything Good for the Environment?

“DO YOU KYOTO?” (Elliptical expression used by Kyoto City Council. Abbreviated as “DYK” hereinafter. See Fig. 2 next page)

“DYK“ is an environmental slogan coined in Japan for environmental promotion throughout the world by referring to Kyoto's role in the development of the Kyoto Protocol. The slogan is another way of saying "Are you doing anything good for the environment?"

Based on the fact that the Kyoto Protocol entered into force on February 16, 2005, the city of Kyoto has designated the 16th of every month as "DYK" Day (a day for doing something good for the environment).
Some organized activities that are part of “DYK” Day implemented by the citizens and businesses in Kyoto include “Lights Down” (an effort to turn off all outdoor lights throughout the Kyoto region), “Kyoto Light Dinner” (where patrons of restaurants enjoy dinner by candlelight or oil-lamp light), “No Car Day” (where people use public transportation instead of personal cars to commute to work, etc.).

Greenhouse Gases

Greenhouse gases influencing global warming include water vapor, CO₂, methane, chlorofluorocarbons, dinitrogen monoxide, amongst others. Of these, water vapor and CO₂ have the highest impact.

Table 1 below presents various characteristics of the major greenhouse gases.¹ Global Warming Potential (GWP) measures the warming effect of a greenhouse gas, while the atmospheric lifetime reflects the total effect of a

<table>
<thead>
<tr>
<th>Greenhouse Gas (Chemical Formula)</th>
<th>Anthropogenic Sources</th>
<th>Atmospheric Lifetime¹ (years)</th>
<th>GWP² (100 Year Time Horizon)</th>
<th>Pre-1750 Tropospheric Concentration (parts per billion)</th>
<th>Current Tropospheric Concentration (parts per billion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Dioxide (CO₂)</td>
<td>Fossil-fuel combustion, Land-use conversion, Cement Production</td>
<td>~100¹</td>
<td>1</td>
<td>280,000</td>
<td>388,500</td>
</tr>
<tr>
<td>Methane (CH₄)</td>
<td>Fossil fuels, Rice paddies, Waste dumps</td>
<td>12²</td>
<td>25</td>
<td>700</td>
<td>1,870</td>
</tr>
<tr>
<td>Nitrous Oxide (N₂O)</td>
<td>Fertilizer, Industrial processes, Combustion</td>
<td>114³</td>
<td>298</td>
<td>270</td>
<td>323</td>
</tr>
<tr>
<td>Tropospheric Ozone (O₃)</td>
<td>Fossil fuel combustion, Industrial emissions, Chemical solvents</td>
<td>hours-days</td>
<td>N.A.</td>
<td>25</td>
<td>34</td>
</tr>
<tr>
<td>CFC-12 (CCl₂F₂)</td>
<td>Liquid coolants, Foams</td>
<td>100</td>
<td>10,900</td>
<td>0</td>
<td>0.534</td>
</tr>
<tr>
<td>HCFC-22 (CCl₃F)</td>
<td>Refrigerants</td>
<td>12</td>
<td>1,810</td>
<td>0</td>
<td>0.218</td>
</tr>
<tr>
<td>Sulfur Hexafluoride (SF₆)</td>
<td>Dielectric fluid</td>
<td>3,200</td>
<td>22,800</td>
<td>0</td>
<td>0.01</td>
</tr>
</tbody>
</table>

1. The atmospheric lifetime is used to characterize the decay of an instantaneous pulse input to the atmosphere, and can be likened to the time it takes that pulse input to decay to 0.368 (1/e) of its original value.

2. The Global Warming Potential (GWP) provides a simple measure of the radiative effects of emissions of various greenhouse gases, integrated over a specified time horizon, relative to an equal mass of CO₂ emissions.
specific greenhouse gas after taking into account global sink availability. The lifetime indicates how long the gas remains in the atmosphere and increased radiative forcing quantifies the contribution to additional heating over an area. The vast majority of emissions are carbon dioxide, followed by methane and nitrous oxide. Lesser amounts of CFC-12, HCFC-22, Perfluoroethane and Sulfur Hexafluoride are also emitted and their contribution to global warming is magnified by their high GWP, although their total contribution is still small compared to the other gases.

Although water vapor is not listed in the table, water vapor is the most abundant greenhouse gas in the atmosphere – naturally, it is indispensable for animal and plant life. Greenhouse gases are not entirely baddies. Why is water vapor important? The average temperature of the earth is currently around 14°C. Without the water vapor in the atmosphere, the average temperature would fall as low as -19°C! Greenhouse gases are making our earth comfortable to live in. However, if we continue using as much fossil fuel as we do, the concentration of CO2 in the atmosphere will increase and global warming will become dangerous. The concentration of CO2 in the air was ca. 340 ppm in 1984, while it was ca. 400 ppm in 2014 and the amount is still rising.

Global warming has already influenced people's lives in many ways. For example, it has led to heavy regional rainfalls, dangerous elevations of sea levels, and outbreaks of dengue fever in Japan. In order to reduce global warming, we should eliminate CO2 emissions, and even decrease the amount of CO2 already present by capturing it.

“3Rs”

The Ministry of Economy, Trade and Industry (METI) is promoting the "3Rs" in order to create a sustainable society, that is, a society that maintains a balance between the environment and the economy. The term the “3Rs” comes from the expression "Reduce, Reuse, and Recycle." The “3Rs” can also be applied to CO2.

“Reduce”

“Reduce” means using fewer resources in the first place. In the case of CO2, this means using renewable en-
ergies such as solar, wind, biomass, small-scale hydraulic, and geothermal power instead of fossil fuels. Another way to reduce the level of CO$_2$ in the atmosphere is to capture and store it. In fact, there are several ongoing “Carbon Capture and Storage (CCS)” projects in Japan. METI has started a large-scale CCS demonstration project in the Tomakomai Area in Hokkaido that will operate from 2012 to 2020 to develop an overall CCS system, starting with compression and capture of the CO$_2$ gas to eventual storage of the captured gas.

How does geological storage of CO$_2$ work? In CCS projects, CO$_2$ is stored in geological reservoirs deep under the ground. CO$_2$ captured from industrial processes is injected into appropriate rock formations deep underground, thereby permanently removing it from the atmosphere. Numerous international studies continue to show that CCS is essential in meeting global climate targets. Now is the time to move on from arguments about its experimental nature or that it has not yet been applied at scale to fossil fuel power plants. Furthermore, the progress in CCS technology development in high carbon intensive industries such as cement, iron and steel, and chemicals is necessary as well. In around 2020, several CCS projects in the world would be under operation.

“Reuse”

As for “reuse” of captured CO$_2$, “Enhanced Oil Recovery (EOR) using CO$_2$” is one means that has many economic and environmental benefits. How does CO$_2$-EOR work? Most commonly, CO$_2$-EOR works by injecting CO$_2$ into already developed oil fields where it mixes with and “releases” the oil from the formation, thereby freeing it to
move to production wells. CO$_2$ that emerges with the oil is separated in above-ground facilities and re-injected into the formation. CO$_2$-EOR projects attempt to create closed-loop systems where the CO$_2$ is injected, produces oil, is stored in the formation or is recaptured and recycled back into the injection well. Today, most of the CO$_2$ used in EOR operations is from natural underground ‘domes’. With the natural supply of CO$_2$ being limited, man-made CO$_2$ from the captured emissions from power plants and industrial facilities (e.g., fertilizer production, ethanol production, and cement and steel plants) can be used to boost oil production through EOR. Once CO$_2$ is captured from these facilities, it is compressed and transported by pipeline to oil fields.

“Recycle”

The recycling of CO$_2$ can be performed in several ways. Since the very beginning of life on earth, photosynthesis by plants has been a vital process. Photosynthesis is used by plants and other organisms to convert light energy, normally from the Sun, into chemical energy that can be later released to fuel the organisms' activities. This chemical energy is stored in carbohydrate molecules, such as sugars, which are synthesized from CO$_2$ and water. In 1967, Prof. Fujishima in Japan discovered an unexpected phenomenon. When he exposed a titanium oxide electrode in an aqueous solution to strong light, bubbles of oxygen gas were released from the surface of the electrode and of hydrogen gas from the counter electrode, though none were emitted when the light was switched off. Based on this discovery, artificial photosynthesis has become an area of active research, and in the future, artificial photosynthesis will allow CO$_2$ to be reduced to organic chemicals that can store light energy in the form of chemical compounds.

In Kyoto, a development project entitled “Next-generation Energy System Creation Strategy for Kyoto”, subsidized by the Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT), is currently underway. The concept of this project is to contribute to the solution of the world’s energy and environmental problems by harnessing the expertise of various institutions and actors in Kyoto in a collaboration between industry,
academia, and government. One of the goals of this program is research into and development of an energy storage system that can chemically store power, such as the development of new fuels that use exhausted CO₂ as a basic component. There are several themes related to energy storage in this project, such as the separation and storage of CO₂ using a novel membranes and the reduction of CO₂ to methanol with novel catalytic system, amongst others.

**Conclusion**

Global warming and CO₂ reduction is of great concern throughout the world. Base-load electric power generation in Japan is provided by nuclear energy and the burning of coal. Even in Germany, in 2012, 46% of electricity generation depended on the use of coal-fired electricity plants (http://www.jepic.or.jp/data/gl_date/gl_date03.html).

We must continue to move forward on all the measures described in this paper to prevent global warming and make the earth a safe and habitable place for all.

**End Notes:**

10. THE GLOBAL STATUS OF CCS 2014 Summary Report
11. http://neori.org/resources-on-CO2-eor/how-CO2-eor-works/