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Mini Review

Global Warming and Reduction of Environmental Carbon Dioxide Concentration

HIBINO Kenichi [1*] (k.hibino7214@hotmail.co.jp)

[1] Imex Japan Co., Ltd. Kyoto, Japan.

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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, CO_2, 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 CO_2 emissions in 2020 by 3.8 % from their levels in 2005. The Japanese government announced that in 2013 CO_2 emissions were up 0.8% compared with 2005. (Fig.1 below)[1]

Are You Doing Anything Good for the Environment?

"DO YOU KYOTO?"[2] (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).

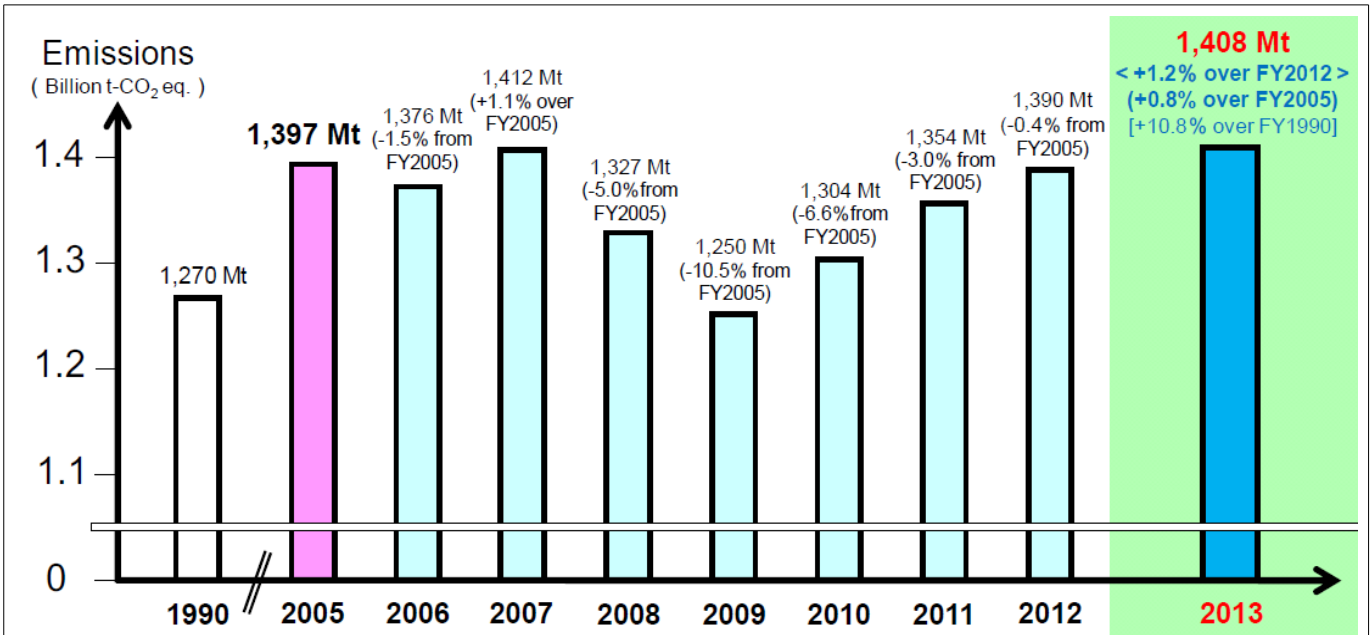


Fig 1: Japan's national greenhouse gas emissions in FY2013 (final figures)

Fig 2: The "DYK" logo asks "Are You Doing Anything 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 candle-light 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, CO_2, methane, chlorofluorocarbons, dinitrogen monoxide, amongst others. Of these, water vapor and CO_2 have the highest impact.

Table 1 below presents various characteristics of the major greenhouse gases.[3] Global Warming Potential (GWP) measures the warming effect of a greenhouse gas, while the atmospheric lifetime reflects the total effect of a

Table 1: Characteristics of major Greenhouse Gases

Greenhouse Gas (Chemical Formula)	**Anthropogenic Sources**	**Atmospheric Lifetime[1]** (years)	**GWP[2]** (100 Year Time Horizon)	Pre-1750 Tropospheric Concentration (parts per billion)	Current Tropospheric Concentration (parts per billion)
Carbon Dioxide (CO_2)	Fossil-fuel combustion, Land-use conversion, Cement Production	~100[1]	1	280,000	388,500
Methane (CH_4)	Fossil fuels, Rice paddies, Waste dumps	12[1]	25	700	1,870
Nitrous Oxide (N_2O)	Fertilizer, Industrial processes, Combustion	114[1]	298	270	323
Tropospheric Ozone (O_3)	Fossil fuel combustion, Industrial emissions, Chemical solvents	hours-days	N.A.	25	34
CFC-12 (CCL_2F_2)	Liquid coolants, Foams	100	10,900	0	0.534
HCFC-22 (CCl_2F_2)	Refrigerants	12	1,810	0	0.218
Sulfur Hexaflouride (SF_6)	Dielectric fluid	3,200	22,800	0	0.01

1. *The atmospheric lifetime is used to characterize the decay of an instanenous pulse input to the atmosphere, and can be likened to the time it takes that pulse input to decay to 0.368 (l/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.*

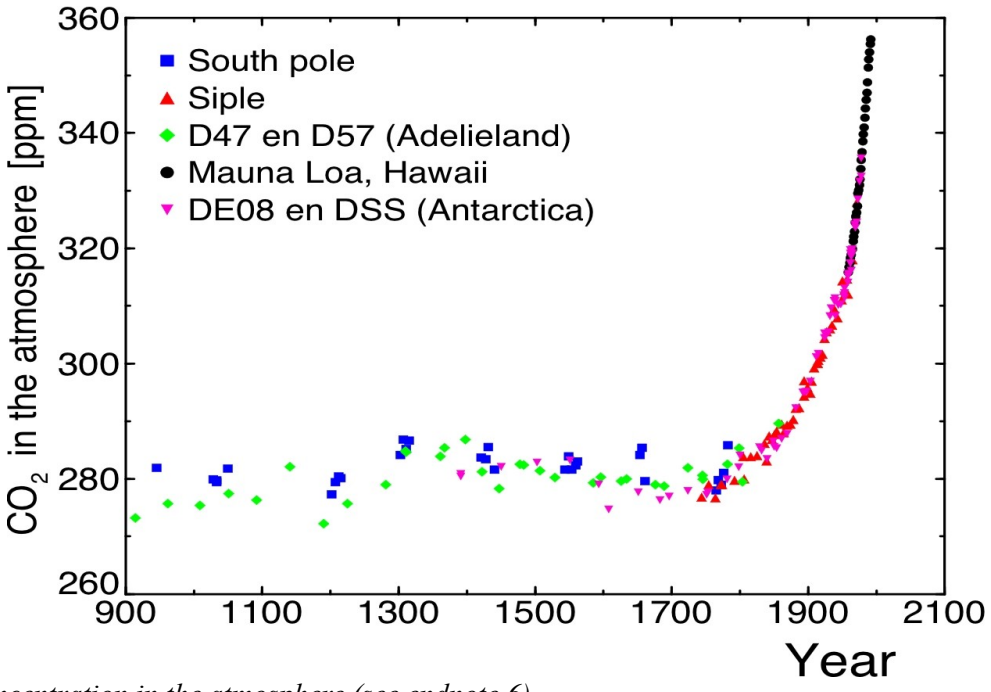


Fig.3. CO2 concentration in the atmosphere (see endnote 6)

Over this 30 year period, the average atmospheric temperature increased by 0.2ºC. There are many factors that influence temperatures in different regions of the globe however the recent increase in the emission of CO_2 is definitely one of the most significant causes of the rise in global temperatures (see endnote 7). It is estimated that if greenhouse gas emissions continue to rise, the average atmospheric temperature will, in the worst-case, have risen by 4.8°C by the year 2100.

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[4]. Lesser amounts of CFC-12, HCFC-22, Perflouroethane and Sulfur Hexaflouride 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 14ºC. Without the water vapor in the atmosphere, the average temperature would fall as low as -19ºC! Greenhouse gases are making our earth comfortable to live in.[5] However, if we continue using as much fossil fuel as we do, the concentration of CO_2 in the atmosphere[6] will increase and global warming will become dangerous[7]. The concentration of CO_2 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 CO_2 emissions, and even decrease the amount of CO_2 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 CO_2.[8]

“Reduce”

“ Reduce" means using fewer resources in the first place. In the case of CO_2, 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.[9]

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.[10]

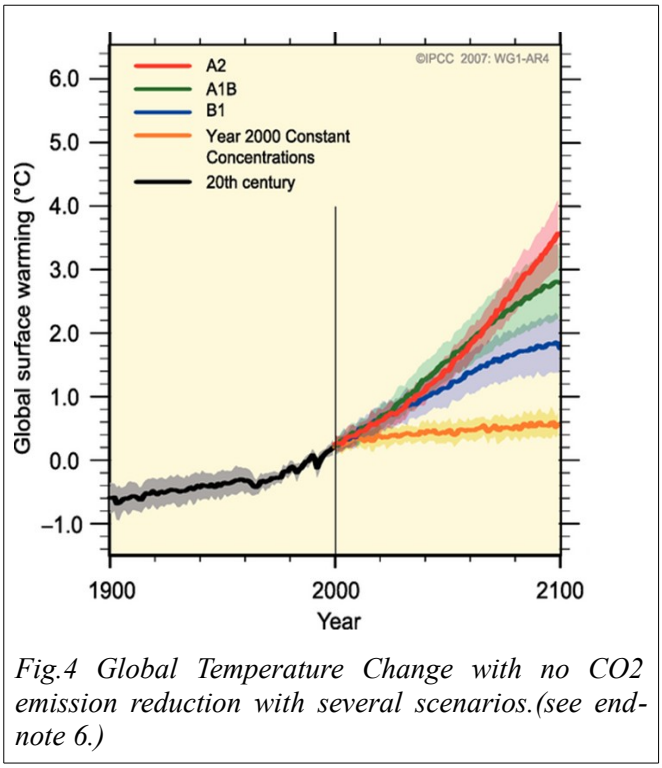


Fig.4 Global Temperature Change with no CO2 emission reduction with several scenarios.(see endnote 6.)

"Reuse"

As for "reuse" of captured CO_2, "Enhanced Oil Recovery (EOR) using CO_2"[11] 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

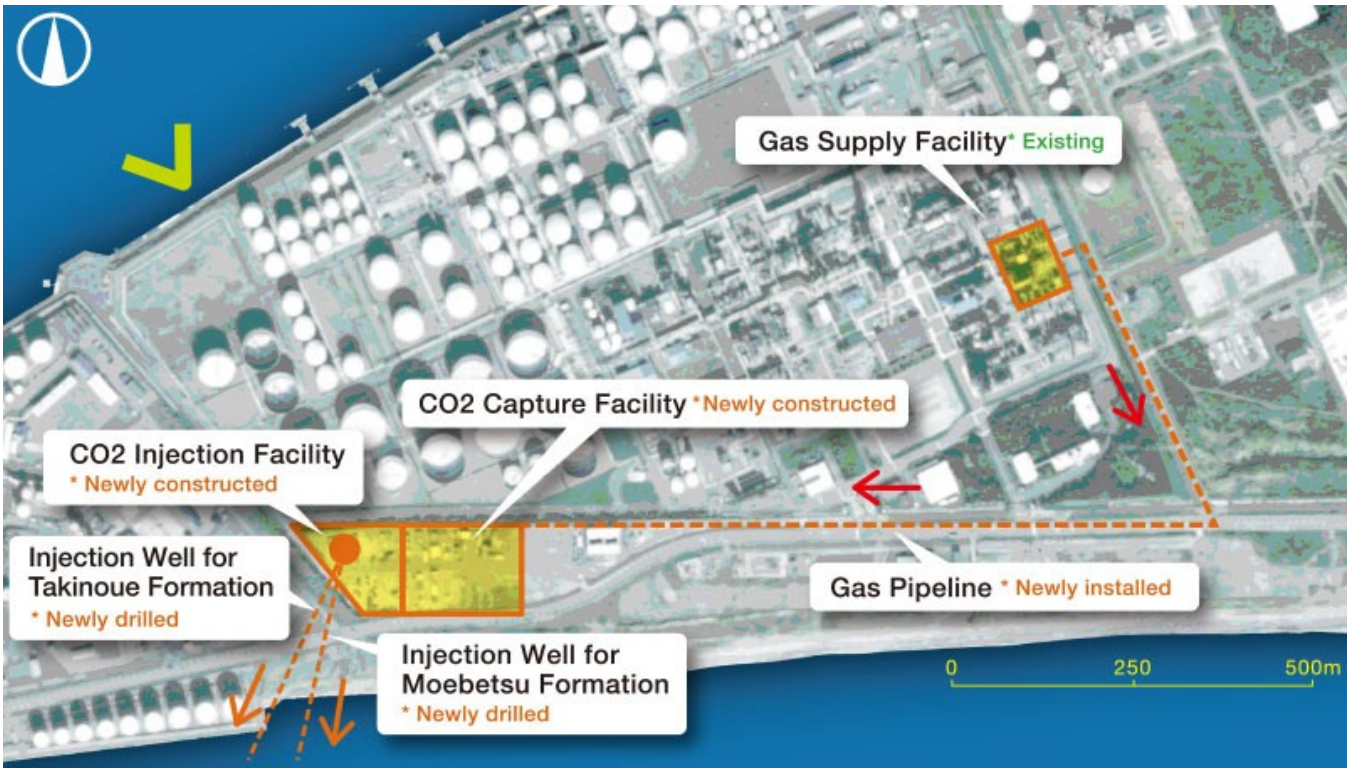
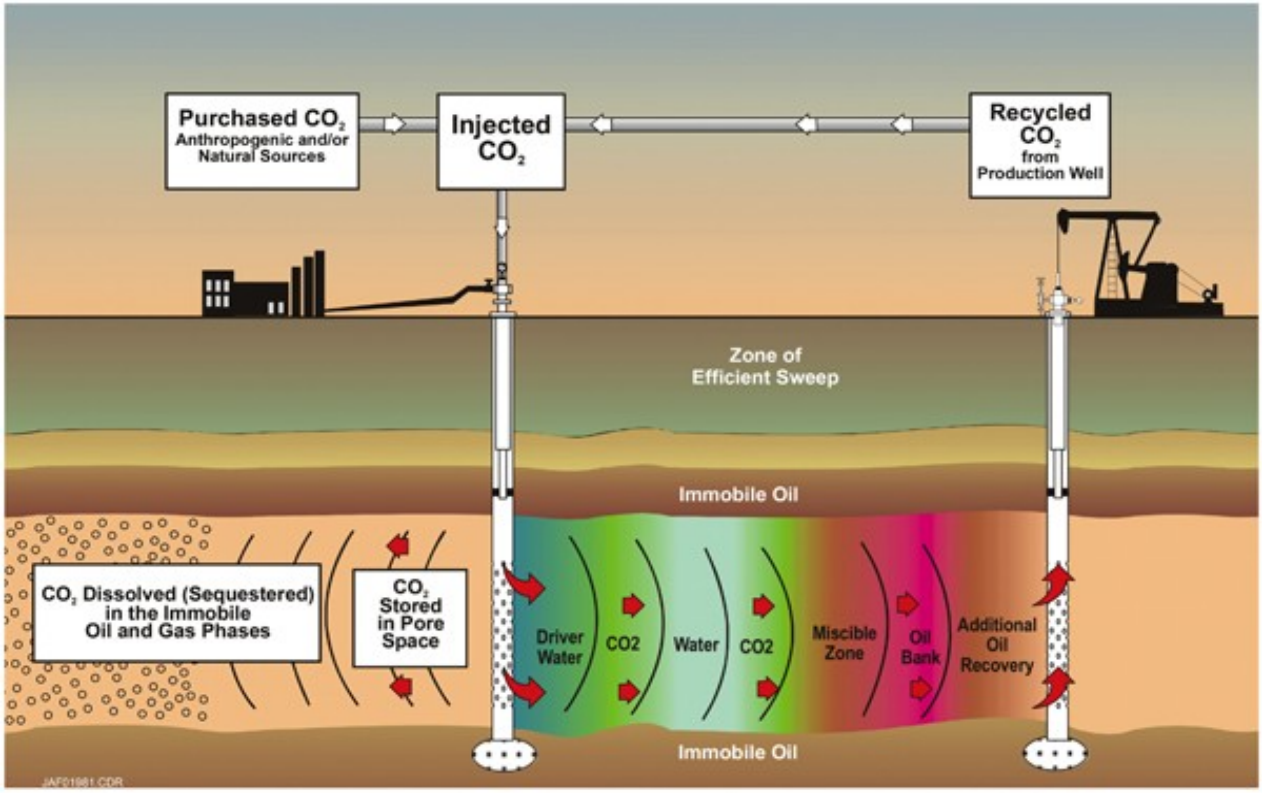


Fig. 5. CCS Demonstration Project at Tomakomai area in Hokkaido (see endnote 9)



Source: Advanced Resources International and Melzer Consulting, Optimization of CO_2 Storage in CO_2 Enhanced Oil Recovery Projects, prepared for UK Department of Energy & Climate Change, November 2010.

Fig.6 Enhanced Oil Recovery (EOR) (see endnote 11)

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.[12] 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.[13] 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 CO_2 as a basic component. There are several themes related to energy storage in this project, such as the separation and storage of CO_2 using a novel membranes and the reduction of CO_2 to methanol with novel catalytic system, amongst others.

Conclusion

Global warming and CO_2 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:

1 www.env.go.jp/press/files/en/601.pdf
2 http://doyou-kyoto.com/dyk/index_en.html
3 http://www.c2es.org/facts-figures/main-ghgs#one
4 http://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_SPM_FINAL.pdf
5 http://www.data.jma.go.jp/cpdinfo/chishiki_ondanka/p03.html
6 http://iter.rma.ac.be/en/sustain/Whyweneed/index.php
7 http://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_SPM_FINAL.pdf
8 http://www.meti.go.jp/policy/recycle/main/english/index.html
9 http://www.japanccs.com/en/business/demonstration/
10 THE GLOBAL STATUS OF CCS 2014 Summary Report
11 http://neori.org/resources-on-CO2-eor/how-CO2-eor-works/
12 "Discovery and applications of photocatalysis — Creating a comfortable future by making use of light energy". Japan Nanonet Bulletin Issue 44, 12 May 2005.
13 http://www.resik.jp/activities_en