

Global Warming Countermeasures

—Current Situation and Future Prospects—

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ABSTRACT

The world is currently under threat of destruction. The Arctic ice is melting, and abnormal weather conditions such as severe droughts and hurricanes have been reported around the world. Global warming is said to be the primary cause of these anomalies. What can be done to save the world from the danger of destruction? This paper first explains the global warming mechanism with reference to its main causes. It then proceeds to describe the environmental governance undertaken by Japan to resolve the problem, and finally, it gives an account of current technology for vehicles, which are responsible for the majority of carbon dioxide emissions.

KEYWORDS : Global warming, Environmental governance, Clean energy

1. What is Global Warming?

1.1 The Global Warming Mechanism

Abnormal weather conditions such as severe droughts and hurricanes are occurring around the world while sea levels are rising due to the melting of polar ice. The principal cause is considered to be global warming due to the rising concentration of carbon dioxide in the atmosphere [1] [2]. By the year 2100, our intense industrial activities and transportation will have caused the average global temperature to rise by 5°C [3] [4] [5]. Therefore, let us examine the mechanism behind global warming which is driven by the rising concentration of carbon dioxide. Approximately half of the blackbody radiation from the surface of the Sun—where the temperature is 6000°C—comprises electromagnetic waves in the visible spectrum, with wavelengths between 400

nm and 700nm. The remainder lies in the infrared (between 700nm and 1000nm) and ultraviolet (under 400nm) regions. The energy input received from the Sun E_{input} and the energy output from the earth's surface E_{output} are in equilibrium. E_{input} is given by Eq. (1).

$$E_{input} = (1 - A) \pi R^2 S_0 \quad (1)$$

where A is the proportion of sunlight that is reflected (i.e., the albedo), R is the radius of the earth, and S_0 is the solar constant (the incoming solar energy radiated perpendicular to a unit area of the earth's surface). According to the Stefan-Boltzmann equation, the energy output from the earth per unit area E_{black} is given by Eq. (2).

$$E_{black} = \sigma T_{eq}^4 \quad (2)$$

where σ is the Stefan-Boltzmann constant and T_{eq} is the temperature at equilibrium. Since the surface area of the earth is $4\pi R^2$, E_{output} is given by Eq. (3).

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$$E_{output} = 2\pi R^2 \sigma T_{eq}^4 \quad (3)$$

Therefore, T_{eq} is as given by Eq. (4).

$$T_{eq} = 4\sqrt{\frac{(1-A)S_0}{4\sigma}} \quad (4)$$

According to Eq. (4), the equilibrium temperature, T_{eq} , is -18°C . However, the average global temperature is actually 15°C . This temperature difference of 33°C is due to substances in the earth's atmosphere that absorb infrared radiation from the earth, which is then emitted back towards the earth. This is known as the "greenhouse effect", and gases in the earth's atmosphere that absorb infrared radiation are called "greenhouse gases". Molecules that absorb infrared radiation are those in which the polarity changes due to molecular vibration. Figure 1 depicts the vibration of carbon dioxide and water molecules.

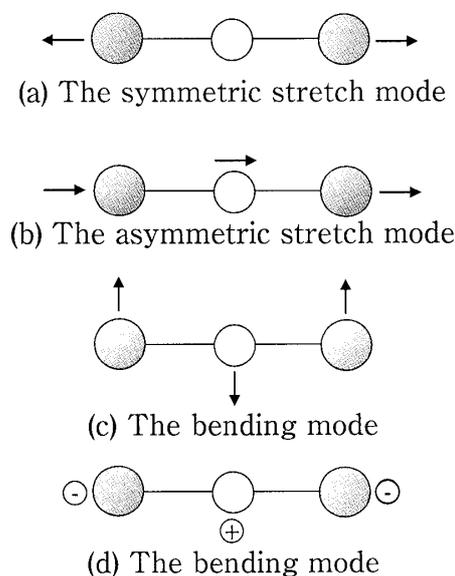


Fig. 1 The vibration mode of Carbon dioxide.

Accordingly, the temperature at the earth's surfaces increases with the concentration of greenhouse gases in the atmosphere. From the industrial revolution until 1998, carbon dioxide was the main contributor to global warming

caused by man-made emissions of greenhouse gases.

The discussion so far has assumed man-made emissions of carbon dioxide to be the cause of global warming. However, there is a theory that it is due to solar activity [6], which will be discussed in another paper.

1.2 Current Damage Due to Global Warming

Global warming is increasing the average global surface temperature but the increases in temperature vary from location to location. Furthermore, they also change with time. As the surface temperature distribution changes, so do pressure patterns, which is considered to be the cause of unusual weather conditions. S. B. Goldenberg *et al.* [7] reported that increased hurricane activity in the North Atlantic was due to a rise in the surface temperature of the ocean there, and P. A. Stott *et al.* [8] reported that greenhouse gas emissions were the cause of the recent heat waves.

1.3 Nations' Carbon Dioxide Emission Levels and Reduction Targets

Figure 2 shows the proportion of carbon dioxide emitted by various countries around the world. America is the highest emitter of carbon dioxide, accounting for approximately 20% of total emissions. Japan, with less than one quarter of the emissions of America, is in fourth place, behind China and Russia [9]. America also has the highest per-capita emission level, being twice that of Japan and nine times that of China.

The targets for greenhouse gas reductions stipulated in the Kyoto Protocol are given in Table 1. As indicated in the table, US President Bush said that there was no scientific basis behind the methodology of the Kyoto Protocol, and withdrew from it. It is well known that a

member of an NGO threw a pie in the face of the American representative because America's stance was vague at the COP 6 meeting held in Hague, Holland (Fig.3)[10].

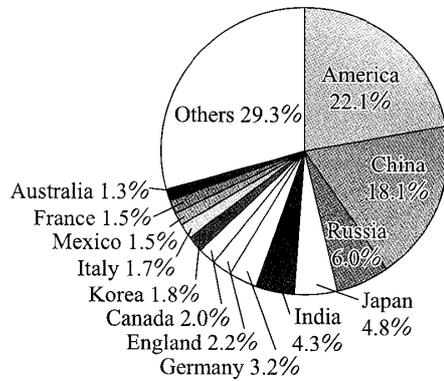


Fig.2 Ratio of the amount of CO₂ emissions in each country (2004).



Fig.3 American representative to whom pie was thrown out (Reuters/Aflo).

Table 1 The goal of CO₂ emission reductions for each countries.

Country	Goal
European Union	- 8 %
America (refusal)	- 7 %
Japan Canada Hungry Poland	- 6 %
Russia New Zealand Ukraine	0
Australia	+ 8 %
Iceland	+10%

2. Japan's Environmental Governance

2.1 The Basic Environment Law

The backbone of Japan's environmental administration is the Basic Environment Law. It was enacted in 1993, emanating from the achievements of the Earth Summit held in June 1992. The purpose of this law was not just to integrate the areas of environmental protection and pollution, but also to play a role in the welfare of future generations of citizens and humanity by tackling global environmental issues [11]. The Government and industry have undertaken a range of activities to reduce carbon dioxide emissions on the basis of the Basic Environment Law.

2.2 Voluntary Action Plan on the Environment

The Voluntary Action Plan on the Environment is a plan for voluntary controls on carbon dioxide, drawn up by the Nippon Keidanren (Japan Business Federation) in June 1997. The plan set objectives whereby the industrial sector and the energy conversion sector would endeavor to cut CO₂ emissions to fiscal 1990 levels or less by fiscal 2010, and progress is reviewed annually. A total of 60 companies and organizations including those in the consumer and transport sectors and 35 business sectors in the industrial and energy conversion sectors are participating in the Voluntary Action Plan on the Environment; this accounts for around 40% of Japan's total emissions and approximately 80% of the emissions due to the industrial and energy conversion sectors. The FY 2006 follow-up review was held jointly with the Industrial Structure Council of the Ministry of Economy, Trade and Industry, and the Central Environmental Council of the Ministry of the Environment. At the review, business sectors that appear to be on track to achieve their targets were encouraged

to increase their targets, while the process of obtaining a clear picture of how the Kyoto mechanism was being implemented by various business sectors continued.

2.3 The Kyoto Mechanism

The Kyoto Mechanism was accepted under the Kyoto Protocol. It is a system whereby, the developed countries from the signatories to the protocol, which were saddled with legally binding emission reduction targets for greenhouse gases, could purchase emission quotas from other countries in order to meet those targets, and if greenhouse gases were reduced other countries, that reduction could be counted towards the developed country's reduction. The specific procedures are given below.

- Joint Implementation (JI) : a system whereby a developed country may invest in a greenhouse gas reduction project in another developed country, and use the reduction towards fulfilling its own target.
- Clean Development Mechanism (CDM) : a system whereby a developed country can invest in a greenhouse gas reduction project in a developing country, and use the reduction towards fulfilling its own target.
- Emissions Trading (ET) : a system whereby developed countries can trade emission units amongst themselves to enable them to meet their reduction targets [12].

2.4 Domestic Emissions Trading

Domestic emissions trading is a scheme under which emissions quotas (the amount of greenhouse gases a business may emit) are set, and if a company exceeds its emissions quota, then it may purchase the excess quota from another company that is actually under its quota, and thus be deemed to have reduced its emissions

(Fig.4)[13]. Domestic emissions trading could be described as a more cost-effective method of reducing environmentally harmful substances than controlling emissions, since companies can choose to purchase emissions quota from another company if it is cheaper to buy quota than to reduce greenhouse gases.

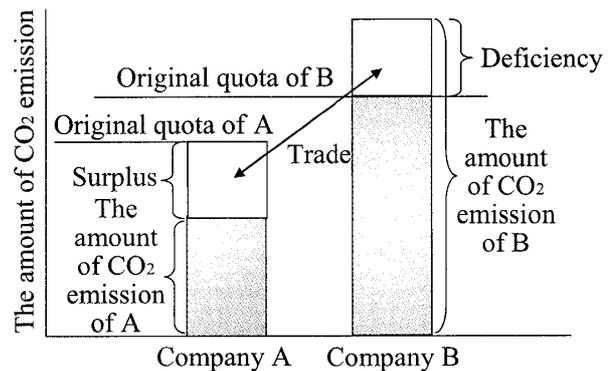


Fig. 4 The trade system in each companies.

2.5 Carbon Tax (Environmental Tax)

Carbon tax (environmental tax) is a tax levied in accordance with carbon dioxide emissions, as a measure to counter global warming. It is intended to provide a financial incentive to reduce emissions of carbon dioxide, a cause of global warming, by levying a tax based on the amount of carbon dioxide emission when fossil fuels are burned, and at the same time, to provide funding for other countermeasures to global warming. In Japan, it was sometimes referred to as the “anti-global warming tax”, but in the Concrete Proposals for an Environmental Tax, compiled by the Ministry of the Environment in 2005, this tax scheme was termed the “environmental tax”. Provisional estimates of a monthly burden of around 180yen per household have been released to promote its introduction. These proposals indicate that a regulatory tax system to counter global warming is considered more appropriate than a surcharge system, under which those who benefit and those who cause emissions pay, since

it is difficult to determine directly the extent of benefit or cause of those responsible for emissions [14].

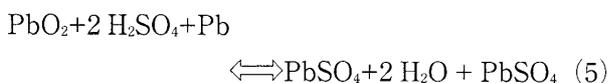
3. Technology to Prevent Global Warming

3.1 Automobiles

Gasoline or diesel vehicles that are fueled by gasoline or light oils obtained by refining petroleum emit large quantities of carbon dioxide, and are one cause of global warming. Carbon dioxide emissions can be reduced by using methanol or methane as fuel, but this results in the emission of formaldehyde, which is harmful to humans, and so this solution necessitates other countermeasures. Therefore, there has recently been enthusiastic development of electric vehicles (EV), hybrid vehicles (HV), and fuel cell vehicles (FCV) in order to overcome these problems.

3.1.1 Electric Vehicles (EV)

Electric vehicles generate their driving force from electrical energy stored in a battery that powers an electric motor. Current vehicles use lead-acid batteries, which rely on the chemical reaction expressed in the following equation: (Eq.5).



At present, there are no alternatives to lead-acid batteries. The batteries for electric vehicles are large and the space available for passengers and items is more restricted than in conventional vehicles. This issue can be overcome by using high-quality materials such as aluminum instead, but a considerable increase in cost is unavoidable.

3.1.2 Hybrid Vehicles

Hybrid vehicles were developed to compensate for the drawbacks with electric vehicles described above. They are usually driven by a motor, but assistance is provided using gasoline or diesel. The Toyota Prius, a five-seat hybrid car which went on sale in 1997, runs for 31km on a liter of fuel, more than twice the fuel economy of a conventional car in the same class (Fig.5(a)) [15]. Meanwhile, in 1999, Honda launched Insight, a two-seat hybrid car that can run for 35km on one liter of fuel (Fig.5(b)) [16].



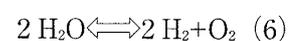
(a) Prius (Toyota)



(b) Insight (Honda)
Fig.5 Hybrid Vehicles.

3.1.3 Fuel Cell Vehicles

Fuel cell vehicles obtain electrical energy from a reaction that is the reverse of water electrolysis. This reaction is expressed by the following chemical equation: (Eq.6)



Their history is about 20 years longer than the above-mentioned lead-acid batteries. The principle is exceedingly simple but the issues concerning their high production cost, ability to be used in winter, and cruising distance still remain. In particular, if fuel cells are to become practical, then it is necessary to reduce the cost of the separators between the cells that make up the stack (i.e., the electrolyte membrane through which hydrogen ions pass) and the catalyst, which is made from an expensive precious metal.

3.2 Energy

As previously mentioned, it has been decided that Japan is to achieve a 6% cut in carbon dioxide emissions by 2010. New energy sources, which do not use fossil fuels, such as oil, are attracting attention as a specific measure toward attaining this target. Solar and wind power generation, and biomass, which produce no carbon dioxide emissions, are described below.

3.2.1 Solar Power Generation

Solar cells are composed of p- and n-type semiconductors, as shown in Fig. 6. When sunlight is absorbed by a solar cell, positively charged holes and negatively charged electrons are generated in the semiconductor. The holes accumulate in the p-type material, and the electrons gather in the n-type material. When a load is attached to the solar cell, a current flows to the load, and so

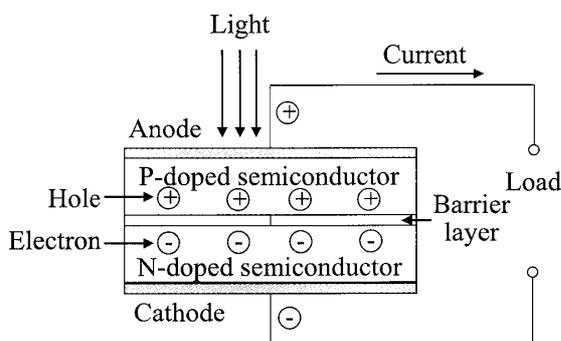


Fig. 6 Mechanism of solar cell.

electricity can be extracted. However, issues facing solar power generation are that it cannot be used at night, the amount of power produced depends on the weather, and that the cost per watt is more expensive than for conventional power generation facilities.

3.2.2 Wind Power Generation

Wind power is generated by the force of the wind turning a turbine, and this motion is then used to drive a generator. The turbine is set up so that it changes direction to face the wind so that the maximum power possible is always produced. If the wind is too strong, such as during a typhoon, a variable pitch mechanism comes into operation so that the wind does not turn the turbine, in order to prevent damage to it. Problems associated with wind power are that the amount of power generated fluctuates, it can cause noise pollution in its vicinity, and unexpectedly strong winds or lightning may damage the turbine.

3.3.3 Biomass

Biomass refers to a renewable organic resource derived from animal and plant material such as waste from domestic animals, food scraps, and wood chips. Biomass consists primarily of the elements carbon, hydrogen, and oxygen. Carbon dioxide, formed when the carbon oxidizes, and water, formed when the hydrogen oxidizes, exist naturally. Plants use energy from sunlight to make biomass from carbon dioxide and water, with oxygen as a byproduct. Thus, since biomass is a highly reducible compound, it can be used as biofuel without upsetting the balance of nature.

4. Conclusion

The paper has described in detail the causes of global warming, and described specific counter-

measures, from both a technical and a political perspective. Global warming is said to be attributed to carbon dioxide emissions due to human activity, but there is no conclusive proof. There are many secondary writings, but few original works. As mentioned in this paper, global warming may be caused by solar activity. An objective analysis of the current state of the global environment is imperative to solve this problem.

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