Overview 1

Accelerating Global Warming and Countermeasure Technologies

Chapter 1

Accelerating Global Warming

Global warming has been accelerating. The term "global warming" is now widely recognized, but in reality expectable outcomes and its impacts on our lives are not thoroughly understood by people.

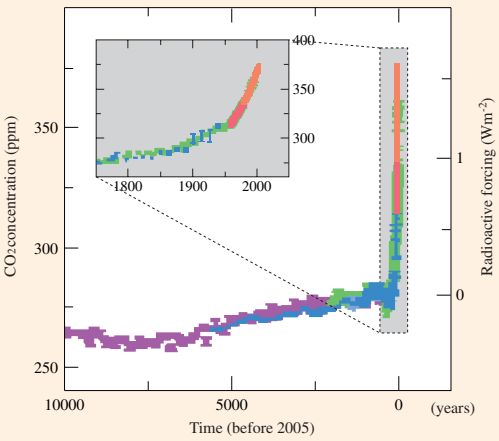
1. We are Currently Facing Accelerating Global Warming

The Intergovernmental Panel on Climate Change (IPCC), which is a framework to estimate the climate change caused by greenhouse gases (GHG), to assess its potential impact on nature, society and the economy and to assess options for mitigation. It is currently finalizing its Fourth Assessment Report (AR4).

According to the report issued by the IPPC's Working Group I (WG1), which presents the physical basis of Climate Change, the global atmospheric concentration of carbon dioxide has increased 1.4 times from a pre-industrial value of about 280 ppm to 379 ppm in 2005. The report also explains that the updated 100-year linear trend (1906 to 2005) of global mean surface temperatures is 0.74°C [0.56°C to 0.92°C]. In addition, the linear warming trend over the last 50 years (0.13°C [0.10°C to 0.16°C] per decade) is nearly twice that for the last 100 year.

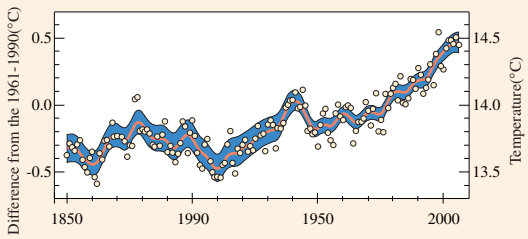
The AR4 WG1 report (the IPPC report issued by its Working Group I for the Fourth Assessment Report) says that eleven of the last twelve years (1995–2006, excluding 1996) rank among the 12 warmest years in the instrumental record of global surface temperature (the average of near-surface air temperature over land and sea surface temperature) since 1850 (Figure 1-3). The IPPC's Third Assessment Report issued

Figure 1-1: Changing CO_2 concentration from ice core and modern data



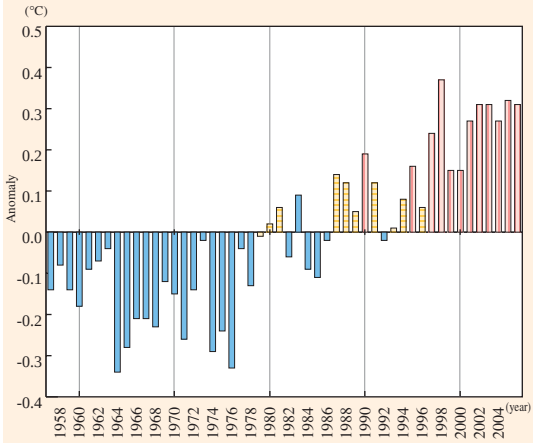
Source: *IPCC AR4 WG1 Report*

Figure 1-2: Changing global average temperature



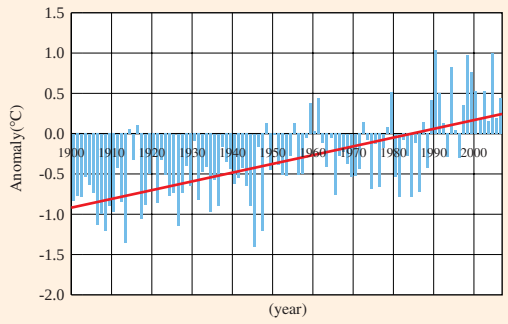
Source: *IPCC AR4 WG1 Report*

Figure 1-3: Annual Anomalies of Surface Temperature Anomalies for the past fifty years



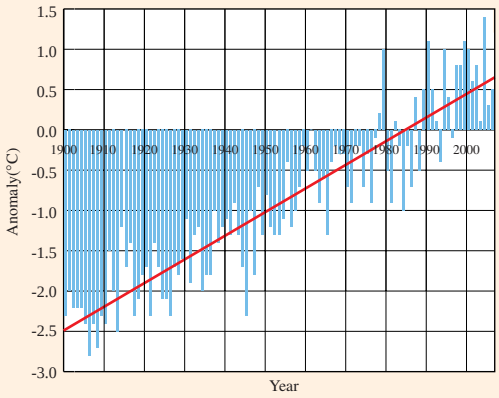
Note 1: Red bars indicate the warmest twelve years since 1850.
Note 2: Anomalies are deviations from normal (1971 - 2000 average).
Source: Compiled by the Ministry of the Environment based on the Japan Meteorological Agency data.

Figure 1-4: Yearly mean temperature anomalies in Japan



Note 1: The data is based on the past observation records of monthly mean temperatures in Abashiri, Nemuro, Suttsu, Yamagata, Ishinomaki, Fushiki (Takaoka City), Nagano, Mito, Iida, Choshi, Sakai, Hamada, Hikone, Miyazaki, Tadotsu, Naze and Ishigakijima .
Note 2: The bars indicate anomalies against normal (for thirty years from 1971 – 2000 average of the 17 stations).
Note 3: The red line indicates a long-term linear trend.
Source: Compiled by the Ministry of the Environment based on the Japan Meteorological Agency data.

Figure 1-5: Annual Average Temperature Anomalies in Tokyo



Note 1: The bars indicate anomalies against normal (for thirty years from 1971 to 2000).
Note 2: The red line indicates a long-term linear trend.
Source: Compiled from the Japan Meteorological Agency data by the Ministry of the Environment.

in 2001 explains globally it is very likely that the 1990s was the warmest decade in the instrumental record (1861–2000), but annual global mean temperatures on record since 2000 exhibit an trend that exceed the 1990s pace.

Japan also experiences a long-term upward tendency as to annual average surface temperatures, at a rate of 1.07°C per 100 years. Especially in and after the 1990s, we have had many warmer-than-normal years (Figure 1-4).

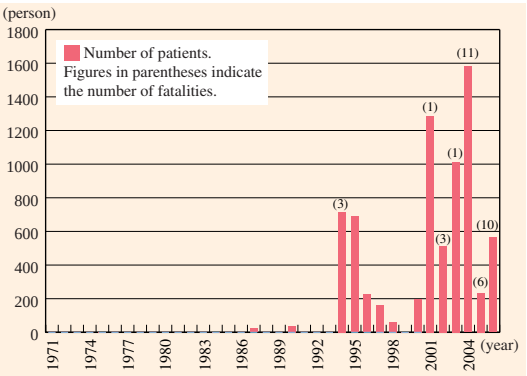
The data in Figure 1-4 is based on the past observation records of monthly mean temperatures in seventeen geographically scattered non-urbanized locations nationwide, selected from those that have a meteorological observatory and a history of continuous weather observation since 1898. In urban areas, due to the heat-island phenomenon and other urbanization impacts, the upward trend is more prominent (Figure 1-5).

Such changes, estimated to be caused by increasing atmospheric CO_2 concentration and rising temperature, have been emerging here and there in various places in the world.

a. Extreme hot weather

In the summer of 2003, the central and western areas of Europe suffered a heat wave of unprecedented magnitude. More than 10,000 people died in France, and throughout Europe, the death toll exceeded 50,000 people. In Zurich, Switzerland, the monthly mean temperature in June was 6.9°C higher than in a normal year. From the end of 2006 to the beginning of 2007, almost all areas in the Northern hemisphere experienced a warm winter. Global monthly mean temperatures in December 2006 and January 2007 registered record highs respectively since 1891. It is estimated that such extreme phenomena are attributed to global warming as a result of increasing GHGs.

Figure 1-6: Changes over time of the number of heat-illness victims in Japan



Source: Compiled from the Japan Meteorological Agency data by the Ministry of the Environment.

Column : Introduction of "Extreme Heat Day"

The Japan Meteorological Agency establishes definitions for temperature-indicating meteorological terms used in weather reports. For example, a "frost day" is a day with a daily minimum temperature below 0°C and a "tropical night" is a night without cooling down below 25°C. For terms indicating hot weather, a "summer day" and a "heat day" are days with daily maximum temperatures of 25°C or higher and 30°C or higher, respectively. From April 2007, the Agency introduced a new summer term, an "extreme heat day", to define a day with a high of 35°C or higher. This reflects the frequently broken records of highs mainly in urban areas.

In 2004, Tokyo (Otemachi) had as many as seventy heat days, registering a record high. A heat day is defined as a day that marked a high of 30°C or higher. (The average number of tropical days per year from 1971 to 2001 was forty-six.) According to the Tokyo Fire Department, a total of 793 people were rushed by ambulance to hospitals within Tokyo due to heat illness during the period between May 1 and September 30 in 2004. (The mean value from 1996 to 2005 is 472 people.) If such extreme hot weather happens more frequently due to global warming in the future, heat-illness victims will probably increase further.

b. Formation of high-intensity tropical cyclone and increasing frequency of heavy rain

There is observational evidence for an increase in intense tropical cyclone activity in the North Atlantic since about 1970, correlated with increases of tropical sea surface temperatures, and the frequency of heavy precipitation events has increased over most land areas (IPCC AR4 WG1 report).

In August 2005, Hurricane Katrina, which hit the Southeastern part of the United States, was a Category 5 hurricane, the highest level under the Saffir-Simpson Hurricane Scale. Katrina caused catastrophe, claiming the lives of more than 1,300 people. According to the ISDR (International Strategy for Disaster Reduction), the damage caused by Katrina within the United States is estimated to be 125 billion dollars (or about 14.4 trillion yen). The NOAA (National Oceanic & Atmospheric Administration of the U.S. Department of Commerce) reported that in 2005 a total of twenty-eight tropical storms formed (tropical storms are defined as tropical cyclone that have a maximum wind speed of 17.2m/s or faster) in the zone stretching from the Northern Atlantic Ocean to the Caribbean Sea, far exceeding the norm in this zone (19), and that fourteen of them developed into hurricanes (defined to be tropical cyclone that have a maximum wind speed of 32.7m/s or faster). If global warming further raises sea-surface temperatures in the tropics in the future, the frequency of high-intensity tropical cyclone is likely to increase.

In Japan, it is also reported that heavy rains are occurring more frequently than ever. According to the "Report on Climate Change 2005" issued by the Japan Metrological Agency, the number of days that have a daily precipitation of 100mm or greater and 200mm or greater respectively increased 1.19 times and 1.46 times, from the 1901-1930 period to the 1975-2004 period.

According to a global warming projection conducted by the Metrological Research Institute, an affiliate of the Japan Meteorological Agency, it is likely under a future warmer climate that the northward progression of the North Pacific High slows down to prolong the rainy season (Baiu) gradually, possibly until as late as August.

Hurricane Katrina Photo: courtesy of NOAA

With a minimum central pressure of 902hPa, Katrina marked the central pressure of 920hPa when it made its landfall.

c. Sea level rise

According to the IPCC AR4 WG1 report, the total 20th-century rise is estimated to be 0.17 [0.12 to 0.22] m. The report says that warming causes the thermal expansion of seawater and ice sheet melting contributing to sea level rise.

Southern Pacific nations are already suffering coastal erosion and the danger of land submergence in many shores. One of them is a small, 26-square-kilometer island nation, Tuvalu, which has a total population of about 10,000 people. Tuvalu is consists of nine atolls, scattered ranging from lat.5 to 10 degrees south, and a half of its habitants is living in its capital, Funafuti. Fogafale Island, where Funafuti is located, is less than 1.5 meters above sea level on average, and has recently started to suffer frequent flooding especially during the period from January to March when the tide level is relatively high. Some of the palm trees on the shore are already unable to stand up, and have fallen into the ocean. We could

Funafuti atoll suffering coastal erosion (in Tuvalu)
Photo: courtery of Shuichi Endo (NGO Tuvalu Overview)

assume that such scene indicates accelerating coastal erosion. There are also reports on salt damage due to the seawater that enters into fields, damaging crops.

On one hand, such salt damage can be attributed to the nation's societal change; increasing population has led to the expansion of residential areas and farming lands into flood-susceptible areas. However, it is estimated that the acceleration of global warming will further exacerbate the said damage.

d. Changes in the habitat conditions of plants and animals

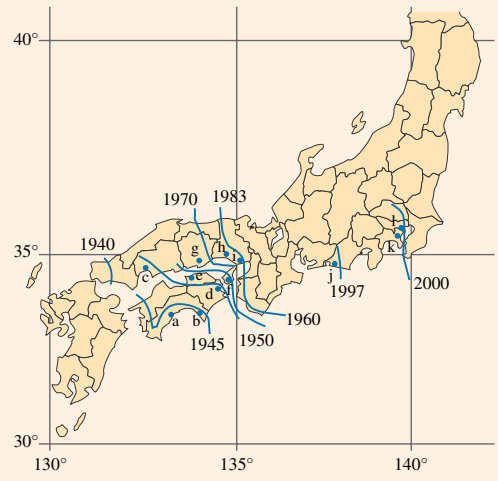
Animals and plants, who are constituents of ecosystems, are sensitively reacting to global warming. There are many reports from all over the world on various changes in their habitat that are attributable to global warming.

The Arctic Circle, which is considered as the area most vulnerable to global warming in the world, facing the peril of the extinction of polar bears. Polar bears depend on seals for food. They hunt seals by capturing them, sneaking up through an ice hole to breathe. Fat from seal meat stored in the body makes it possible for bears to survive. Loss of sea ice as a result of global warming would endanger polar bears because they will not be able to hunt seals easily. Actually, the results of a survey on the average weight of polar bears living in Hudson Bay, Canada, show that they have lost weight in the last few decades, from an average weight of only 230 kg as of 2004, compared to 295 kg in 1980. The weight of 230 kilograms is considered to be close to the minimum level that allows polar bears to maintain the reproductive ability. There have also been reports of polar bear deaths attributable to melting ice. The bears had been forced to swim for long distances and have died due to exhaustion. In 2006, the World Conservation Union (IUNC) classified polar bears into the Red List of Threatened Species as "Vulnerable (VU)."

Coral near Akajima Island of the Kerama Islands, Okinawa Prefecture
Photo: courtesy of by Akajima Marine Science Laboratory

Another example is coral-reef bleaching. Reports of coral bleaching (coral bleaching is the whitening of coral colonies due to the loss of symbiotic zooxanthellae from the tissues of polyps) have been frequently heard from various places around the world. The ecological significance of coral reefs is remarkable, as they serve not only as habitats and egg-laying sites for around 4000 species of fish, but also as natural breakwaters that protect people's homes in coastal areas. Among various factors known to be responsible for coral bleaching, one of the most serious ones recently reported is a stress caused by rising seawater temperature. It has been discovered that during the 1998 El Nino event, which was the severest one in history, as much as 16% of the global coral reefs died or were seriously damaged. Scientists predict that the combined effects of global warming and El Nino, causing further rise of seawater temperatures, could result in coral bleaching which will become much more common. In addition, there is a report warning that accelerating ocean acidification caused by the increase in CO_2 uptake will make it difficult for corals to form a hard protective skeleton of calcium carbonate, and will possibly hamper the growth of corals. The IPCC AR4 WG1 report estimates that projections based on SRES scenarios give reductions in average global surface ocean pH16 of between 0.14 and 0.35 units over the 21st century, adding to the present decrease of 0.1 units since pre-industrial times.

Figure 1-7 Northward expansion of habitats of Papilio memnon Linnaeus



Note: Figures indicate calendar years. Small letters from "a" to "l" indicate twelve cities and locations where temperature analysis was conducted.
Source: "Correlation between the expanding habitats for Papilio memnon Linnaeus and global warming" written by Masahiko Kitahara et al and published through the journal "Butterflies and Moths" issued by the Lepidopterists' Society (52, 2001).

Global warming also causes changes in flora/fauna habitat locations. In Japan, stakeholders are paying close attention to the recent phenomenon of the northward expansion of habitats of

butterflies of southern species such as Papilio memnon Linnaeus (Figure 1-7). Also in recent years, deer habitats have been expanding into mountain areas, causing serious damage to agricultural and forestry businesses. Deer are compelled to migrate in order to avoid heavy snows at the onset of winter, and the said trend of changing deer habitats is considered to correlate with increasing warm areas and global warming.

2. Projections of Global Warming

According to the IPCC AR4 WG1 report, best estimates and likely ranges for global average surface air warming for six SRES emissions marker scenarios are given in this assessment and are shown in figure 1-8. For example, the best estimate for the low scenario (B1) is 1.8°C (likely range is 1.1°C to 2.9°C), and the best estimate for the high scenario (A1FI) is 4.0°C (likely range is 2.4°C to 6.4°C).

The IPCC AR4 WG2 report suggests that approximately 20-30% of plant and animal species assessed so far are likely to be at increased risk of extinction if increases in global average temperature exceed 1.5-2.5°C

Globally, the potential for food production is projected to increase with increases in local average temperature over a range of 1-3°C, but above this it is projected to decrease.

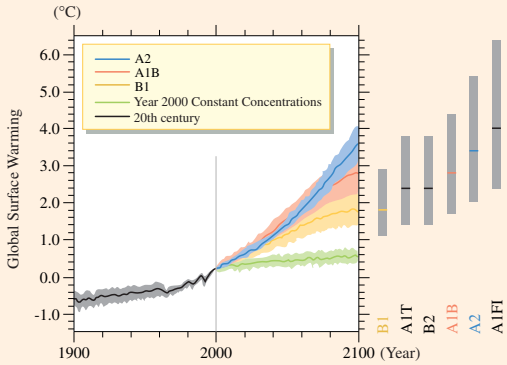
Increases in sea surface temperature of about 1-3°C are projected to result in more frequent coral bleaching events and widespread mortality. With higher temperatures, hundreds of million people are projected to be exposed to water stress.

Over the course of this century, net carbon uptake by terrestrial ecosystems is likely to peak before mid-century and then weaken or even reverse, thus amplifying climate change (See paragraph 5, Section 3 of Chapter 2).

Thus, increases in global mean temperature of less than 1-3°C above 1990 levels, some impacts are projected to produce benefits in some places and some sectors, and produce costs in other places and other sectors. It is very likely that all regions will experience either declines in net benefits or increases in net costs for increases in temperature greater than about 2-3°C.

If the human society continues to emit GHG at the current pace, the said increase level could be exceeded. It can be said that "global warming doomsday clock" is ticking. In order for us to stop this clock from striking catastrophe, it is urgently required to accelerate our efforts to fight against global warming.

Figure 1-8: Projections of the IPCC Special Report on (SRES)



Note: The Emission Scenarios of the IPCC Special Report on Emission Scenarios (SRES)

A1. The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil-intensive (A1FI), non-fossil energy sources (A1T) or a balance across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies).

A2. The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.

B1. The B1 storyline and scenario family describes a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.

B2. The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

An illustrative scenario was chosen for each of the six scenario groups A1B, A1FI, A1T, A2, B1 and B2. All should be considered equally sound.

The SRES scenarios do not include additional climate initiatives, which means that no scenarios are included that explicitly assume implementation of the United Nations Framework Convention on Climate Change or the emissions targets of the Kyoto Protocol.
Source: *IPCC AR4 WG1 report*

3. Mechanism of Global Warming and Necessity of Immediate Actions

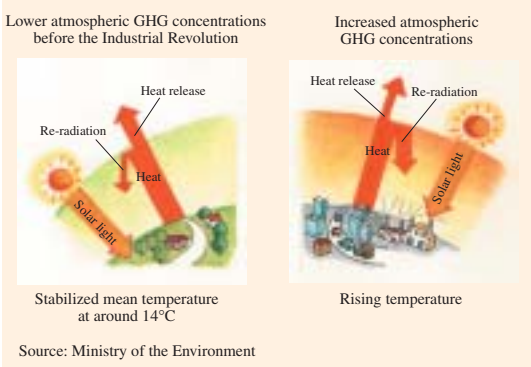
The Earth's temperature depends mainly on the balance of incoming solar energy and outgoing terrestrial radiation.

The Earth is heated by solar light. Then, the Earth radiates infrared, which is absorbed by atmospheric greenhouse gases including carbon dioxide, and the heat is returned to the Earth's surface (re-radiation). Through this process, the Earth's surface temperature is maintained at an average of about 14°C, providing an optimal condition for living creatures.

However, since the Industrial Revolution, the human society has come to consume a large amount of fossil fuels by combusting them, resulting in enormous GHG emissions such as carbon dioxide into the air. This led to the hike in GHG concentrations in the

air, which has increased the atmospheric uptake of radiated heat from the Earth's surface. This has induced higher temperatures throughout the Earth, and that's the mechanism of global warming. Annual fossil carbon dioxide emissions per year in 2001-2005 are estimated to be about 7 billion tons (carbon equivalent; hereinafter referred to as tC. Seven billion tC is equivalent to about 26 billion tons in terms of the amount of carbon dioxide), and this value is expected to further increase in the future. In the meanwhile, the maximum amount of carbon dioxide that can be absorbed yearly by nature is estimated to be about 3 billion tC (or about 11 billion tons in terms of the amount of carbon dioxide). In this light, it is necessary to maintain the GHG balance between emissions and uptake in order to stabilize climate and prevent the expansion of adverse impacts.

Figure 1-9: Mechanism of global warming



Source: Ministry of the Environment

A few scientists strongly doubt this theory that the increase in human-caused CO_2 emissions is the major cause of global warming. However, when we study the trend after the Industrial Revolution and during the latter half of the 20th century in particular, we cannot explain the hike in CO_2 level and temperature without consideration on the human-caused CO_2 emission increase.

Those scientists who doubt the fatal contribution of human-caused carbon dioxide to global warming point out that the current amount of human-caused CO_2 emissions of about 7 billion tC is far below the amount of carbon exchanged among the atmosphere, ocean, and terrestrial biosphere, which is estimated to be 90 billion tC. However, the value "7 billion tC" represents the annual emissions, and the accumulated amount of CO_2 emissions caused by human activities is estimated to be 350 billion tC. This is equivalent to 60% to 70% of the amount of CO_2 remaining in the atmosphere before the Industrial Revolution, and apparently exceeds the CO_2 uptake potential in nature.

There is another theory supported by a few scientists, arguing that the increased CO_2 concentration is not responsible for global warming and that, instead, the rise of temperature is responsible for the increase in CO_2 concentration. This theory alleges that increased sea-surface temperature induces CO_2 release into the air from the ocean, causing the increase in atmospheric CO_2 concentration. However, suppose this alleged mechanism exists, it cannot theoretically explain the fact that CO_2 concentration has rapidly risen for the past few decades, and the cause of the recent temperature hike either.

Recently, science academics of the G8 nations jointly announced the statement (in 2005) that claims urgent actions to be taken by G8 governments over the issue of global warming, on the grounds that most of the warming in recent decades can be attributed to the human-caused increases in CO_2 emissions . The IPCC AR4 WG1 report also supports most of the observed increase in global average temperatures since the mid-20th century is very likely (probability of occurrence is more than 90%) due to the observed increase in anthropogenic greenhouse gas concentrations. Thus, the mechanism that global warming is attributed to human-caused GHG increase in the atmosphere, including carbon dioxide, is a general consensus among majority of scientists in the world.

According to the IPCC AR4 WG3 report (the report by Working Group III for the Fourth Assessment Report), there is substantial economic potential for the mitigation of global GHG emissions over the coming decades, that could offset the projected growth of global emissions or reduce emissions below current levels. Bottom-up studies indicate that the economic mitigation potential in 2030 is 9-17 $GtCO_2$-eq/yr in the carbon price of 20 US$/$tCO_2$-eq, and 16-31 $GtCO_2$-eq/yr for 100 US$/$tCO_2$-eq.

Table 1-1: Stabilization scenario

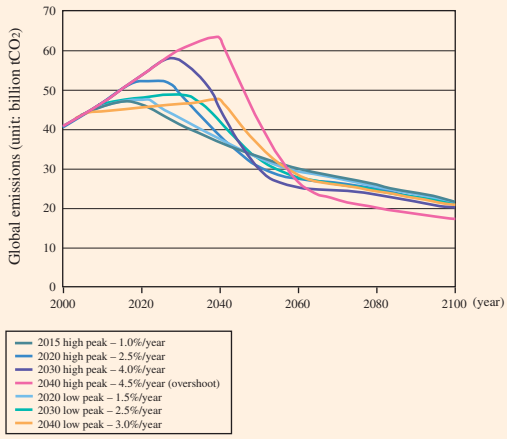
Category	CO_2 concentration	CO_2-eq Concentration	Global mean temperature increase above pre-industrial at equilibrium, using "best estimate" climate sensitivity	Peak year for CO_2 emissions	Change in global CO_2 emissions in 2050
	ppm	ppm	°C	Year	%
Ⅰ	350～400	445～490	2.0～2.4	2000～2015	-85～ -50
Ⅱ	400～440	490～535	2.4～2.8	2000～2020	-60～ -30
Ⅲ	440～485	535～590	2.8～3.2	2010～2030	-30～ +5
Ⅳ	485～570	590～710	3.2～4.0	2020～2060	+10～ +60
Ⅴ	570～660	710～855	4.0～4.9	2050～2080	+25～ +85
Ⅵ	660～790	855～1130	4.9～6.1	2060～2090	+90～+140

Source: Compiled by the Ministry of the Environment based on *the IPCC AR4 WG3 report*

It has also been suggested that the lower the stabilization level, the more quickly the peak and decline would need to occur. Mitigation efforts over the next two or three decades will have a major long-term impact on the availability of opportunities to avoid a rise in the global mean temperature and the corresponding climate change. (Table 1-1). In 2050, the global average macro-economic cost for multi-gas mitigation towards stabilization between 710 and 445 ppm CO_2-eq would be between a 1% gain to a 5.5% decrease of global GDP.

The report also suggests that the range of stabilization levels assessed can be achieved by way of a deployment of a portfolio of technologies that are either currently available or expected to reach the commercialization stage in the coming decades, provided that appropriate and effective incentives are provided for development, acquisition, deployment and diffusion of said technologies and for addressing related barriers. While the report admits that a wide variety of national policies and instruments are available to governments to create the incentives for mitigation action and that there are advantages and disadvantages inherent to any given instrument, the report shows some selected instruments, including regulations and standards, taxes and charges, tradable permits, voluntary agreements, information instruments, and RD&D, etc.

Figure 1-10 : Illustrative emissions paths to stabilize GHG concentration at 550ppm (CO_2 equivalent)



Note: "Overshoot" indicates a path in which the atmospheric GHG concentration peaks above the stabilization level and then falls.
Source: Nicholas Stern "*The Economics of Climate Change*" Cambridge University Press (2006)

It is also pointed out that policies that provide a price of carbon could create incentives for producers and consumers to significantly invest in low-GHG products. Such policies could include economic instruments, government funding and regulation.

The Stern Review on the economics of climate change, submitted to the U.K. Government and the HM Treasury in October 2006 by Sir Nicholas Stern, a former Chief Economist of the World Bank, says it is still not too late. The Review argues that climate change could seriously deteriorate economic growth and development but that there is still time to avoid the worst climate change impact provided that strong collective action begins now. The Review also suggests that the benefits of strong, early action on climate change outweigh the costs and thus demands immediate international actions to address climate change. According to Stern, delay in taking action on climate change would eventually make it necessary to accept higher mitigation costs, because emissions must be reduced more rapidly to achieve the same stabilization goal, and emission will peak at a higher level (Figure 1-10).

In order for us to avoid the risk of inviting an irreparable outcome, it is essential to start fighting against global warming decisively under the precautionary principle. We need to take the status quo of global warming seriously and promote international cooperation to address the issue effectively and efficiently.