How Developing Countries Can Engage in GHG Reduction: A Case Study for China

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Abstract
It has been clearly recognized that future global climate change will limit the possibilities for sustainable development in China. To minimize these negative effects, as a practical strategy, we suggest that the Chinese government engage in international cooperation as a key contributor in the prevention of global warming. This suggestion results from numerical estimations of China's greenhouse gas (GHG) emission trends accompanied with economic growth up to 2100. The results show that China's gross domestic product (GDP), measured in terms of purchasing power parity (PPP), may overtake the sum of the GDPs of the United States and Canada in 2020. It is predicted that GDP per capita may reach US$20,000 and $80,000 in 2050 and 2100 respectively; meanwhile, CO_2 emissions in China will increase from 6.6 bil. tons (in carbon equivalent units) in 1990 to 54.6 bil. tons in 2100. This means that the global peak concentration of GHG cannot be practically reduced without significant contributions from China. For international cooperation in mitigating global climate change, we introduce a new option, "per-capita emission restricted by assigned amount," as an accounting rule for GHG reduction. This baseline classifies global CO_2 reduction actions into three categories: compulsory reduction, self-imposed reduction, and voluntary reduction. We suggest that China contribute to world CO_2 reduction according to the following timetable: voluntary reduction until 2012, self-imposed reduction until 2020, and compulsory reduction from 2020. The simulation results also indicate that China can benefit from this strategy in terms of improvements in its domestic economy and environment, for instance by reducing fossil fuel consumption and the emission of pollutants.

Keywords: China, sustainable development, energy, climate change, measures

1. Introduction

The United Nations Framework Convention on Climate Change (UNFCCC) was signed at the 1992 Earth Summit in Rio de Janeiro (UNFCCC 1996-2000). The key point agreed upon by all participating countries is to "stabilize greenhouse gas (GHG) concentrations in the atmosphere at a level that would prevent dangerous man-made interference with the climate system." Since Annex-1 countries (a list of developed countries that are members of the Organization of Economic Cooperation and Development, plus the countries of the former Soviet Union and the Eastern Bloc) and non-Annex-1 countries (developing countries, including China) differ in their past and current GHG emissions in both total and

per-capita amounts, the framework was developed on the basis of equity and "common but differentiated responsibility," as well as the sustainable development of developing countries. Therefore, under Article 4 of the UNFCCC, different commitments have been introduced for emissions reduction in developed and developing countries.

As one of the non-Annex-1 countries, in principle it is not compulsory for China to implement the Conference of Parties III (COP3) (UN 1998) for direct reduction of emissions. However, with the rapid growth of its economy, China's coal-dominated energy consumption has increased dramatically. In 2004, China's CO_2 emissions reached 1.2 bil. tons, accounting for 14% of the world total, and that trend appears to be increasing in subsequent years (BSC 2005a). Therefore, whether China will participate in the convention, or in other words, when China will implement the Kyoto Protocol in the same way as Annex-1 countries, is an issue that commands the attention of the world.

Regarding GHG emissions reduction by China, there are three basic issues that have to be discussed. These are 1) scenarios -- what measures China should undertake to join the convention; 2) methodology -- how to reduce CO_2 emissions under the convention; and 3) timing -- a timetable for China's participation in the convention.

In this study, based on numerical estimations of trends in China's economic growth, energy consumption, and environmental burden, we analyzed the current status, challenges, key issues, and future strategies for China's GHG emissions reduction.

2. Why China? Energy consumption and environmental impact

The Chinese economy has been growing since 1980, with its GDP increasing at an annual rate above 9.0% for more than 20 years. Associated with this rapid economic growth has been a dramatic increase in energy consumption in China. For instance, within the last five years, energy consumption grew about 70%, from 912 Mtoe (million tons of oil equivalent) in 2000 to 1557 Mtoe in 2004. This increase was greater than the country's total energy consumption from 1981 to 2000. Meanwhile, within these same five years, China's coal production increased from 686 to 1533 Mtoe; oil imports increased from 73.84 to 143.61 Mtoe (a 69.77 Mtoe increase); and total electric power capacity increased from 319 mil. kWs to 508 mil. kWs (a 189 mil. kWs increase) (BSC 2005b). Such rapid growth in energy consumption is far beyond the estimates of recent international energy outlook reports (e.g. EIA 2005; IEA 2002; OECD 2004-2005) and even beyond the estimates of the Chinese Energy Research Institute (Zhou, Dai et al. 2003). Energy consumption estimates for China by several such institutes are shown in Figure 1.

The Chinese government has planned to increase the country's GDP in the next 10 and 20 years with respective targets of 2 and 4 times that of 2005 (Zhou, Dai et al. 2003). To reach these targets, China must maintain annual economic growth of 7.2% for the first 20 years of the 21st century. This entails tremendous energy consumption, especially if heavy industries (the large energy-consuming industries, such as iron and steel, ferrous metals, petrochemicals, cement, etc.) continue to play an important role in China's GDP. Also associated with this target is a change in living standards as personal consumption shifts toward modern household electronic appliances and automobiles. Rapid urbanization will also demand much more energy for building construction and city development. All of these changes can be expressed by exact data. Energy consumption per person in China was 1.1 tons in 2004, which is only 75% of the world average, 14% of that of the United States

and Canada, and 20% of that of Japan (UN 1998; IEA 2002; Chinese Government 2006). To reach the government's GDP target, China's energy demands will have to exceed 3000 Mtoe by 2020, about 2 tons per person. This number is calculated by setting a time step of three years. Clearly, a large amount of emissions, sulfur dioxide (SO_2) and carbon dioxide (CO_2), will be produced as well. These emissions will no longer be a problem just for China, but will exert a great environmental impact on the whole world.

To examine these energy and environmental issues in detail, we offer three representative examples of such issues as follows:

(1) Serious power shortages (energy issue)

In recent years, power shortages have become a serious problem all over China, especially in coastal areas. As shown in Figure 1, power consumption reached 1009 bil. kWh in 2003, with a power generation facility capacity of 380 mil. kW and a power shortage of 20 mil. kW. It is estimated that this power shortage will continue at least through 2006 (SBJ 2005). Furthermore, it is estimated that in 2010 electricity consumption will be up to 3500 bil. kWh with a power generation facility capacity over 670 mil. kW; in 2020 these amounts will be 4500 bil. kWh and 950 mil. kW respectively. Thus the 2020 amounts are predicted to more than double those of 2003 (OECD 2004-2005).

(2) Rapid increase in imported crude oil (energy issue)

Concerned with air pollution, the Chinese government has encouraged local governments and industries to use clean energy in recent years. As a result coal consumption has been limited to a certain level while crude oil imports have rapidly increased. In 2003, oil consumption in China reached 260 bil. tons, greater than Japan and ranking second in the world after the United States (BSC 2005a). According to the National Bureau of Statistics of China, imported crude oil in 2004 rose to 120 bil. tons from 91.12 bil. tons in 2003 (BSC 2005a). About 50% came from countries in the Middle East (vs. 85% in the case of Japan) (Chinese Government 2006). The growth in crude oil imports by China appears to have had a significant impact on the world oil market. Increases in global oil prices will also exert a negative influence on the economic development of China.

(3) Increase of environmental burden (environmental issue)

Environmental issues have become a major concern in China today because people have been personally affected by such problems as air pollution (dust particles, CO_2, NOx, SOx), river floodwaters, and sand covering wide regions of the country. Among these issues, air pollution in China is a problem not only for China itself but also for neighboring countries and even the entire globe. This pollution comes from burning fossil fuels, notably coal. In China, the environmental burden per person is not that large. For example, the amount of CO_2 emitted per person is only half that of the world average. However, because of China's large and growing population, rapid economic growth, and coal-concentrated energy consumption, total amounts of emitted SO_2 and CO_2 increased 1.7 and 2.9 times respectively from 1980 to 2005 (UN 1998), almost the same rate as the increase in energy consumption. In particular, CO_2 emissions rose to 660 mil. tons (carbon equivalent units) in 1990, to 850 mil. tons in 2000, and to 1110 mil. tons in 2005 (UN 1998). As a national total

this amount ranks second in the world after the United States. Table 1 shows the details of CO_2 emissions in China.

3. China's responsibility and strategic options in joining UNFCCC

3.1 Factors in emissions reduction by China under UNFCCC

Considering China's current economic growth and environmental burden (especially CO_2 emissions), we suggest that it is a practical option for China to adopt an emissions reduction strategy under the UNFCCC. As regards practical performance, in other words when and how China should attempt to meet Annex-1 style emissions reduction obligations, we will cite two important factors to consider.

Factor 1: The developed countries have had a long period over which to deal with the three stages of economic development, pollution disasters, and global warming. Developing countries like China have to face all three stages at any point in their development. On the other hand, among current environmental issues, China is more vulnerable to concern about the mitigation of local environmental disasters that have intensified with increasing urbanization, such as air pollution, water pollution, and waste, and less about the problem of global warming.

Factor 2: China's CO_2 emissions have the following characteristics: 1) large in total amount; 2) small in per-capita amount; and 3) relatively high in per-GDP emission rate. Among these, characteristic 1 indicates the necessity of reduction; 2 indicates that China has the opportunity to optimize its reduction strategies; and 3 shows that a proper approach to reduction needs to be considered (e.g. the improvement of technologies for energy conservation and efficiency).

3.2 Basic issues for China's participation in UNFCCC

3.2.1 Scenarios: Measures China should undertake for reduction

For developing countries, an important first step is the formulation of practical and acceptable "accounting rules" in advance of enrolling them as participants in the reduction of GHG emissions. Applicable targets and data have been proposed in the reports of the UNFCCC. The Kyoto Protocol sets GHG reduction targets for developed countries (UN 1998). Some suggestions for accounting rules have also been proposed, such as a per-capita emissions standard, a per-GDP emissions standard, and an integrated emissions standard to take per-capita, per-GDP, and population growth rate together into account (Kameyama et al. 2004). It is a fact, however, that no practical accounting rules are currently proposed or stipulated.

Such accounting rules should be effective in actually reducing global GHG emissions (according to the assigned amount of reduction defined by the Kyoto Protocol), equitable to all, efficient, and sustainable. In view of these considerations, we propose here an optional accounting rule for GHG reduction, called the "per-capita emission restricted by assigned amount" accounting rule, defined as follows.

Per-capita net CO_2 emission can be calculated by the following equation:

$$CO_{2net}/P = \left[CO_{2G} - (CO_{2dis} + CO_{2sin})\right]/P$$
$$= (CO_{2G}/E) \times (E/GNP) \times (GNP/P) - (CO_{2dis} + CO_{2sin})/P \quad (1)$$

where CO_{2G} represents total CO_2 emissions from energy consumption E; GNP is the gross national product, CO_{2G}/E represents energy consumption per GNP, CO_{2dis} is the amount of carbon dioxide sequestration, and CO_{2sin} is the so-called carbon sink (for example as provided by forests).

We can obtain the following conclusions from Equation (1) regarding the restriction of per-capita net CO_2 emissions:

(1) To reduce CO_{2G}/E, utilize green energy (solar, hydro, wind, bio-energy and nuclear energy) and fuel conversion (from coal to oil, and from oil to low-carbon fuel such as natural gas).
(2) To reduce E/GNP, promote energy conservation and improve the industrial structure.
(3) To restrict GNP/P to the proper scale, restrict abnormal economic growth and change personal lifestyles.
(4) To increase CO_{2dis}, increase forestation as much as possible.

Generally, the restraint of per-capita CO_2 emissions not only contributes to an overall reduction in CO_2 emissions, but also:

(1) Improves economic efficiency (energy saving and improved industrial structure).
(2) Reduces pollution emissions (fuel conversion, use of green energy).
(3) Improves the structure of energy supplies (reuse of carbide).
(4) Protects the ecosystem.

In other words, the restraint of per-capita net CO_2 emissions will yield such benefits as the development of energy technologies and energy conversion, utilization of green energy, and forestation.

The following is an example of how this accounting rule can be applied.

From the results of the DNE21 model (Yamaji and Fujii 1995) runs shown in Figure 2, we can determine a permissible world CO_2 emission level of 550 ppm for 2100 (Zhou 2004). These results are based on the B2 scenario from the IPCC Special Report on Emissions Scenarios (SRES) and the assumption that atmospheric CO_2 concentration will remain stable during that time (IPCC 2000). Under the assumption that the world population will be 11 billion in 2100, we can express per-capita CO_2 permissible emissions as total CO_2 permissible emissions (the assigned amount established by the Kyoto Protocol) divided by population. This data is used here to serve as a standard for emissions reduction.

In Figure 3, we show estimates for the period from 1990 to 2100 for CO_2 emissions in China, Japan, North America, and countries of the former Soviet Union (CIS and Eastern Europe), under the BAU (business as usual) case. By multiplying the per-capita permissible CO_2 emission shown in Figure 2 by their respective populations, we can estimate the initial emission rights for each country (Zhou 2004).

In addition, the dash lines in Figure 3 marked “COP3 abatement target” show the obligatory reduction goals under the Kyoto Protocol for Japan, North America, and countries of the former Soviet Union (7%, 6% and 0% of 1990 emission amounts, respectively) (UN 1998).

From Figure 3, we can determine that:

(1) Emissions from North America under the BAU case and its COP3 abatement target are much higher than the permissible emission level. If we expect to reach the 550 ppm level to prevent global warming, it is necessary for each country to abide by the permitted emission rate. However, this view does not seem to be accepted by the United States. As a practical strategy for reducing global CO_2 emissions from the viewpoint of fairness and efficiency in attaining the world reduction target, the part of emissions over the permitted value (i.e., the difference between the permitted value and actual emissions) could be traded under the emission trading rules of the Kyoto Protocol.
(2) China, with its very low per-capita emission, may cross the line of permissible emission around 2020 if emission reductions are not considered. This means that China will share the same obligation of emission reduction as developed countries from 2020.

Air is the public property of all human beings on the earth. Everyone should have the same duty to prevent environmental pollution. Even if we disagree over the idea of air pollution or emission "rights," it is fair for everyone to share a common standard for CO_2 emissions. Based as it is on the concept of equality, the accounting rule of "per-capita emission restricted by assigned amount" may be a practical alternative to non-restricted emissions rules. Non-restricted per-capita emission accounting rules face the following issues:

(1) Control of the total population
Obviously no country would like to increase its population only in order to get more emission rights, for it may negatively impact economic growth, especially for developing countries.
(2) How to set the world total permissible emission level (assigned amount unit)
Until the industrial revolution, atmospheric CO_2 concentration was about 280 ppm. Today, after 200 years, this value has reached 370 ppm, and is projected to rise to 800 ppm by 2100 (UN 1998). In this study, our analysis is based on the assumption that 550 ppm will work as a world total permissible emission level for the year 2100. This is a preliminary goal of the UNFCCC for stabilizing GHG concentrations in the atmosphere. On the other hand, currently there is no solid scientific definition of exactly how much GHG concentration should serve as a measure of the breaking of the global climate balance by human activities. Therefore the 550 ppm emission level is only a preliminary reduction goal, which requires further confirmation.
(3) Other issues
There have been extended discussions on how to set a permitted CO_2 emission level, how to calculate the carbon sink effect of forests, issues involving GHG emission-trading scenarios, how to consider the fairness problem between human generations, etc.

3.2.2 Methodology: How China can reduce GHG emissions under UNFCCC

To prevent global warming, several methodologies have been proposed:

(1) "No regrets" options: energy saving, tree planting.
(2) "Less regret" options: introducing new or renewable energies like solar energy.
(3) Specialized strategies for global warming: carbon dioxide sequestration in the ocean and underground.

Methods (1) and (2) are already being applied in China and it is found that they also produce positive side-effects such as promoting economic development, environmental protection and pollution prevention, and improvement of energy structures and supplies.

3.2.3 Timing: When China should reduce CO_2 emissions

The answer to this question is currently one of the key points of U.S.-China negotiations on the climate change issue. If we apply scenarios derived on the basis of "per-capita emission restricted by assigned amount" to the formulation of GHG reduction timetables, there should be no need to distinguish developed countries from developing countries. Based on this accounting rule, China should join the compulsory reduction ranks by 2020, while the United States should reduce emissions immediately.

3.3 Timetable for China's emission reductions

3.3.1 Strategy for China's participation

China is a non-Annex-1 country that is currently not obligated to commit itself to global GHG emission reductions. But this situation will not last forever. Here we will discuss an appropriate timetable for China's emission reductions.

Under the UNFCCC's principle of "common but differentiated responsibility," countries are classified into three groups, as shown in Figure 4: (1) developed countries (e.g. the U.S. and Japan); (2) middle-income countries (e.g. South Korea and Brazil); and (3) developing countries (e.g. China and India). The obligations of the countries in each group vary and can be classified into three types: compulsory reduction (for countries that are required to reduce to a legally binding target value), self-imposed reduction (for countries that are not obligated but have made a self-imposed commitment to a reduction target value), and voluntary reduction (for countries that don't have a reduction target value, but voluntarily adhere to a reduction plan). Currently, the obligations of all countries are for voluntary reduction. By 2008, the developed countries will start their "compulsory reduction" stage; meanwhile the middle-income countries will be expected to abide by their "self-imposed reduction" commitment.

3.3.2 Strategic timetable for China's action

Based on the estimated results shown in Figure 3 and the aforementioned GHG reduction obligations, we propose the following strategic timetable for emission reductions by China. China can act, step by step, in three stages: (1) voluntary stage (to 2012), (2) self-imposed stage (to 2020), and (3) compulsory stage (from 2020).

According to this timetable we draw the following conclusions: (1) China will have to establish a legally binding target value for emissions reduction. (2) Since the Kyoto Protocol only set reduction targets for the first commitment period of 2008-2012, it is unfair to expect China to commit to the same reduction target as a developed country, considering its historic and current emissions status. (3) The legally binding target value should not be set until 2020 because China's emissions may reach the permitted reduction level by that time. When developed countries have already met the reduction target for the first commitment period, China's GDP may be reaching the level of the GDPs of middle-income countries.

4. Conclusion

With a focus on the rapid economic development of China, we performed a numerical simulation of energy consumption and environmental emissions associated with that development to analyze their current state and also to estimate trends for the coming 100 years. On the basis of the results of these simulations, we proposed a plan and a timetable for China's contribution to the mitigation of global climate change. We drew attention to the following points:

1) According to the principle of "common but differentiated responsibility," we suggest that the IPCC implement CO_2 reductions in practice as a voluntary reduction for developing countries, self-imposed reduction for middle-income countries, and compulsory reduction for developed countries, respectively.
2) As an example for developing countries, we suggest that China reduce its CO_2 emissions on a voluntary basis until 2012, then on a self-imposed basis until 2020, and after that on a compulsory basis. We set this timetable based on the accounting rule of "per-capita emission restricted by assigned amount" proposed in this study.
3) It must be mentioned again that China will benefit from implementing CO_2 reduction not only in terms of national economic development, but also of the national environment. This is an eminently acceptable option in light of China's substantial development.

Acknowledgement

As part of the analysis in this study was based on numerical modeling results from the DNE21 model, we hereby thank all participants who have made contributions to the development of the DNE21 model.

Note: About the DNE21 Model

The Dynamic New Earth 21 (DNE21) model (Yamaji and Fujii 1995, RITE 2004) is a global energy optimization model incorporating detailed energy technology, developed by Professors Kenji Yamaji and Yasumasa Fujii et al. of the Research Institute of Innovative Technology for the Earth. This model, which geopolitically divides the world into ten sub-regions, was developed to evaluate technological measures and formulate practical scenarios for CO_2 abatement on the basis of energy demand scenarios for the period 1990-2100. One feature of this model is that it permits technical evaluation based on engineering data for the whole world.

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[List of Figure Legends:]

Figure 1 Comparison of China's electricity demand predicted by various studies. Data sources are International Energy Outlook 2004 (EIA, 2004.4); World Energy Outlook (IEA, 2002.9); Energy Demand and Supply Outlook 2002 (APEC, 2002.9); China's Sustainable Energy Scenarios in 2020 (ERI, 2003.8). This study assumes China GDP growth rates of 7% in the period 2006-2010 and 5% in the period 2011-2020.

Figure 2 World total permissible CO_2 emissions and population forecast

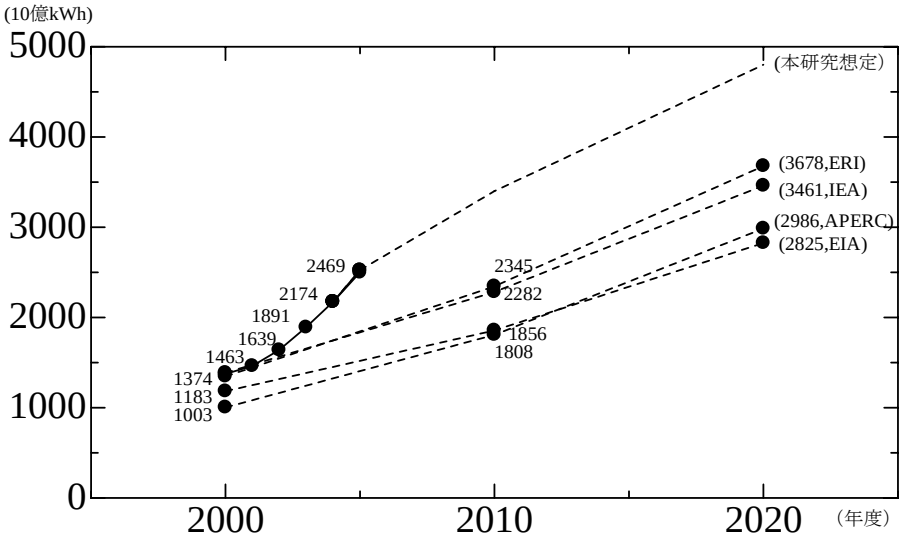
Figure 3 Permissible CO_2 emissions and emissions under BAU case

Figure 4 China's strategic timetable and three-stage theory for UNFCCC participation

Table 1 International comparison of CO_2 emissions (mil. ton-C)

	China	Japan	USA	World
2000	852	320	1,577	6396
2010	1240	343	1835	7910
2020	1720	370	2088	9850

Data for China: results predicted in this study; data for Japan and USA, 2000: refer to EDMC, Energy and Economy Statistical Summary 2005; data for Japan and USA, 2010 and 2020: refer to IEA, World Energy Outlook 2002.



From: International Energy Outlook 2004 (EIA, 2004/04)、World Energy Outlook 2002(IEA, 2002/09); 「APEC Energy Demand and Supply Outlook 2002」(APEC,2002/09); China's Sustainable Energy Scenarios in 2020(ERI, 2003.8); The supposes in this study: GDP growth rates: 7% in the period of 2006～2010, 5% in the period of 2011～2020.

Figure 1 Comparison of electricity demands predicted by various studies

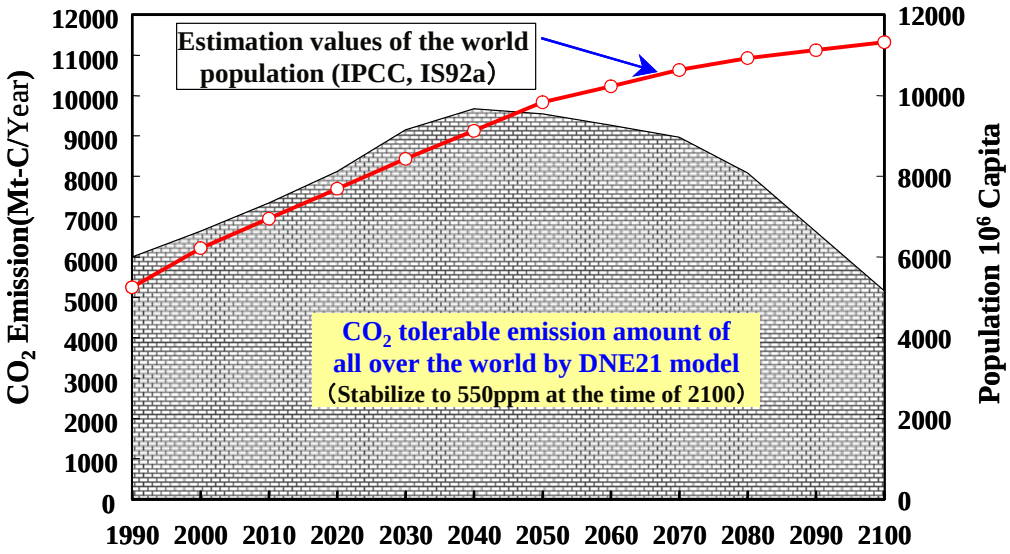


Figure 2 World total allowed CO_2 emission and population forecast

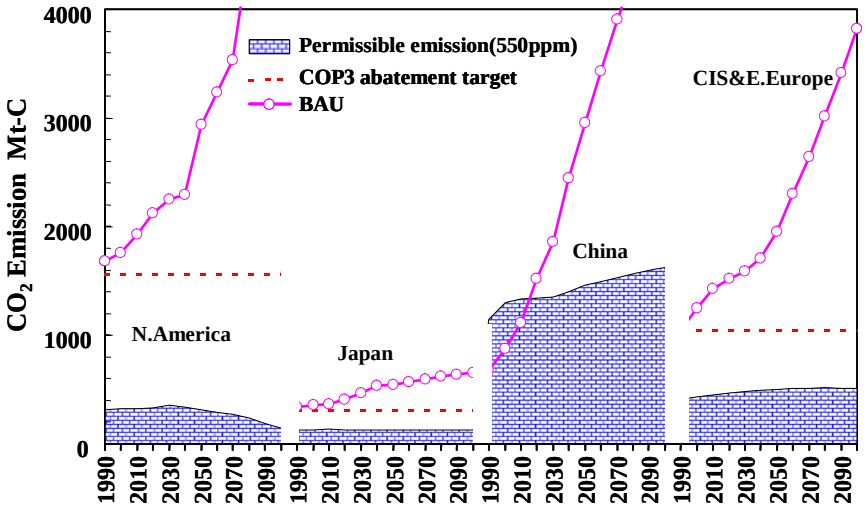


Figure 3 Permitted CO_2 emission and emission under BAU case.

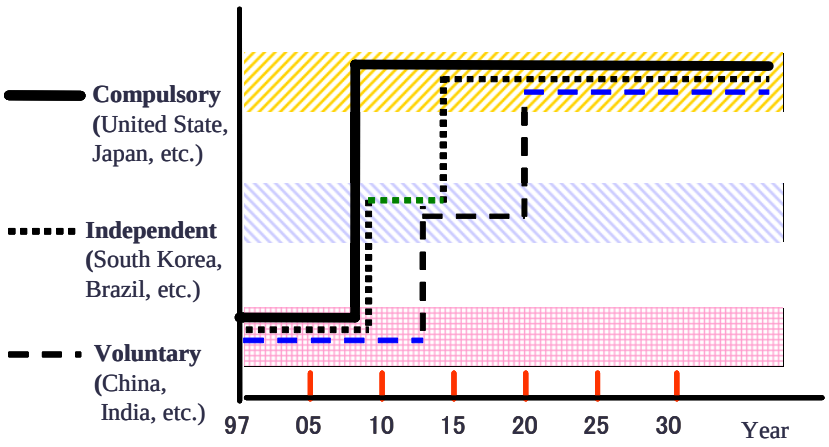


Figure 4 China's strategic timetable and three-stage theory joining in FCCC.