Nuclear Power and the Kyoto Mechanism

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This paper reviews the arguments about nuclear power under the CDM in the COPs, and examines effectiveness of the CDM if it would be used as a means of funds raising that are expected to be the greatest obstacles to introducing nuclear power in the developing countries. Funds that could be raised by Japan in return of the emission rights of greenhouse gases were calculated for the cases in China, as a typical example of developing country whose electricity demand has been increasing rapidly, substituting aged and inefficient Chinese coal-fired thermal power plants with Japanese nuclear power. For comparison, cases substituting with natural gas advanced combined cycle (natural gas ACC) were also calculated. It was found that the CDM could have a function that provides merits to both countries; China would be able to solve her energy and environmental problems simultaneously by introducing nuclear power or natural gas ACC with funds provided by Japan, while Japan would be able to get large amount of emission rights at a low cost and to stimulate her industries by plant export business.

1. Introduction

More than 90 % of the population growth in future is expected to take place in the developing countries, and demands for energy in turn is expected to grow significantly with population growth and economic development. This tendency is particularly noticeable in the developing countries of Asia, and their demands for energy must be met for the time being by consumption of fossil fuels, especially coal. The inevitable outcome will not only be limited to the rapid increase in emissions of the greenhouse and the pollutant gases. It has been pointed out that these countries' dependency on oil supplies from Middle East will increase so much that their energy security will be threaten by such an excessive dependency, and that risks must be spread by diversifying energy sources. As nuclear power plants do not emit greenhouse gases, they are practically reliable and promising option for an energy source that will be required by developing countries striving to achieve high economic growth rates under rapid increase in population, while not deteriorating the global environment.

Features of nuclear power include that it uses many advanced technologies, it handles large quantities of nuclear fuel materials and radioactive materials, it requires a technically advanced infrastructure, and it requires procurement of a high level of funding for power plant construction. Accordingly, not a few developing countries have been following a policy of positively introducing nuclear power, however, it is essential for the country to obtain technical and financial assistance from developed countries in, for example, funding, education and training of operation and maintenance personnel, assurance of safety, and nuclear material control, when a developing country plans to introduce nuclear power plants,.

In December 1997, the Third Conference of Parties to the U.N. Framework Convention on Climate Change (COP-3) held in Kyoto agreed that developed countries should reduce their five year average greenhouse gases emissions for 2008 to 2012 (first commitment period) 5.2% (6% for Japan) below those in 1990. At the same time, the Conference permitted flexible provisions for achieving this goal. These were the joint implementation (JI), the clean development mechanism (CDM) and the emissions trading (ET) known as the "Kyoto Mechanism", and the counting the greenhouse gases absorbed by forests. Of these, the CDM is a system that counts the achievements of projects conducted by developed countries to reduce greenhouse gas emissions in developing countries as emission credits for developed countries. Recognition of the Kyoto

mechanism means attaching specific values to emission rights. This suggests that the CDM can be applied as a mechanism for funds raising and technical transfer, currently significant barriers to the introduction of nuclear power to developing countries. Because it is expected that the developed countries would actively invest in the introduction of nuclear power plants in the developing countries, if the investing countries can get emission reduction credits through the CDM. At present, however, it was agreed at COP-7 "to refrain from using emission reduction units generated from nuclear facilities to meet their commitments" of reducing the greenhouse gas emissions in the commitment period of 2008 to 2012.

This paper reviews the arguments about nuclear power under the CDM in the COPs, and it also examines effectiveness of the CDM if it would be used as a means of funds raising that are expected to be the greatest obstacles to introducing nuclear power in the developing countries. Funds that could be raised by Japan in return of the emission right of greenhouse gases were calculated for the cases in China, as a typical example of developing country whose electricity demand has been increasing rapidly, substituting aged and inefficient Chinese coal-fired thermal power plants with Japanese nuclear power. For comparison, cases substituting with natural gas advanced combined cycle (natural gas ACC) were also calculated.

2. Arguments about Nuclear Power under the CDM in the COPs

Looking at the history of discussions of nuclear power at the COPs, from COP-1 to COP-4 they avoided discussing nuclear issues because of conflicting interests among national governments and non-governmental organizations (NGOs), except that a few NGOs appealed for use of nuclear power at COP-3. However, at COP-5 held in 1999 in the German city of Bonn, the JCO critical accident occurred in Japan immediately before the conference had a huge impact, with many nations including Austria, Denmark, Germany, Greece, Italy, Sweden, and Norway expressing the opinion that nuclear power should not be selected as a means of the CDM and JI. In conclusion, the final statement at COP-5 stated that there were questions with nuclear power in terms of eligibility for the CDM.

At COP-6 held in The Hague in the Netherlands in November 2000, a systematic approach to Kyoto Protocol issues including responses to nuclear power was discussed, however failure to reach international consensus meant the matter was transferred to the resumed COP-6 held at Bonn in July of the following year. Regarding the nuclear CDM, the umbrella countries such as Japan, the United States and Canada, plus China insisted that details on sustainability of the CDM should be determined by discussion between the host country (receiving developing country) and the investing countries, and should not be regulated within the scope of Kyoto Protocol. However, participants from the EU and eastern Europe, most of whom were environmentalists, the oil producing countries and small island countries for whom nuclear power has no benefit, and the South American countries, objected to allowing nuclear power as a means of the CDM. In the end, Chairman Pronk's arbitration draft stated that there were doubts regarding the "sustainability" of nuclear power, so that the countries shown in Annex I (developed countries) should declared not to use nuclear power in the CDM.

At COP-7 held at Marrakech in Morocco in 2001, institutional designs of the Kyoto mechanism was discussed, and an agreement reached with few practical restrictions on its utilization, however it was decided for the CDM as "Recognizing that Parties included in Annex I are to refrain from using certified emission reductions generated from nuclear facilities to meet their commitments" in the first commitment period (2008 through 2012).

Thus nuclear power cannot be used as a means of the CDM at present, however it is in fact one of the most effective options for actually reducing greenhouse gases in the long term. Discussions for the second commitment period (from 2013) onward have only just commenced, and the use of nuclear power will be discussed again and possibly admitted as a practical option for the CDM in the future.

3. Case Studies for China

3.1 Energy situation in China

In China, electricity consumption has risen rapidly due to the expanding industrial activity and improvement in living standards accompanying economic growth. In fact electricity shortages are now reality in Shanghai and its environs, and in many other areas. More than 80% of electricity in China relies on thermal power generation, 95% of which is supplied by coal-fired power plants. In

1995, more than 40% of transport by railroad and state-owned canals in China was used for coal transportation. This causes other problems, including an adverse effect on the Chinese economy due to the negative impact of coal on transport networks, in addition to an increase in unhealthy air pollution and greenhouse gases emission caused by enormous coal burning.

Conversion to oil as a more convenient fuel has begun, resulting in growth in energy consumption that saw China become a net oil importer in 1993. This could threaten the energy security of the whole of Asia, due to excessive dependence on Middle East oil. China therefore has a major motivation to develop economical energy sources with fewer environmental and resource limitations such as nuclear power and natural gas.

In particular nuclear power discharges no greenhouse gases and has fewer fuel transport problems, only requiring transport of around 30 tons of fuel annually for operation of a light water reactor (LWR) of 1,000 MW electricity output. And if plutonium recovered from spent fuels of LWRs is recycled using fast breeder reactors (FBRs), this will eliminate anxiety in energy security caused by depletion in uranium resources. Therefore, China has high expectations of nuclear power as a future energy source with plutonium recycling by FBRs, as does Japan. The most significant issue is that of finding funds for the construction work required to push ahead with conversion to advanced power sources such as nuclear power and natural gas ACC.

In Japan meanwhile, nuclear power has not been introduced as planned due to a slowdown in the growth of electricity demand, and difficulties in siting, leaving the nuclear power industry in dire straits. The most effective key to overcoming this stagnation is the export of nuclear systems to developing countries experiencing high growth in electricity demand, however exporting to developing countries is hindered by the huge construction cost of nuclear power plants, and lack of infrastructure for nuclear exports in Japan.

3.2 Concept of the CDM Based on Advanced Power Technologies

Aged coal-fired thermal power plants operated in China are poor in thermal efficiency, emitting huge volumes of CO_2 per unit of electricity generation. We conducted a quantitative assessment on how efficiently construction costs can be recovered by emission rights of corresponding value when Japan invests in a project to apply the CDM to shut down aged Chinese coal-fired power plants and replace them with low CO_2 emission nuclear power or natural gas ACC. In the assessment, an LWR was selected for the nuclear power, and for the purpose of simplicity CO_2 was the only greenhouse gas considered.

In this case, a so-called Win-Win scenario may be expected with benefits for both Japan and China. Benefits for China include:

(1) Procurement of funds required to replace aged coal-fired power plants with advanced power plants, and acquisition of advanced power plant technologies and information,

(2) Reduction in CO_2, NOx, and SOx emissions by replacing aged coal-fired power plants with advanced power plants, and

(3) Increase in energy security with diversification of energy sources by introduction of nuclear and natural gas.

On the other hand, the benefits for Japan in investing in such projects include:

(1) Obtaining large amount of greenhouse gas emission credits at reasonable prices, and

(2) Stimulating her industries by plant export business.

3.3 CO_2 emissions from power plants and emission right prices

The average weights of CO_2 (carbon equivalent base, same below) emitted from power plants in Japan by life-cycle per unit of electricity generation, as shown in Fig. 1, is calculated as 7.7 g-C/kWh for LWR, 141.5 g-C/kWh (including fuel originated: 111.1 g-C/kWh) for natural gas ACC and 266.0 g-C/kWh (including fuel originated: 241.9 g-C/kWh) for pulverized coal-fired thermal power plant operated at 39.5% of the plant thermal efficiency [1].

Meanwhile, average thermal efficiency of coal-fired power plants in China in 1990 was considerably lower at 28.8% [2]. Average fuel-originated CO_2 emission from these plants is estimated 331.7 g-C/kWh, which is larger than 241.9 g-C/kWh for advanced pulverized coal-fired power plant shown in Fig. 1 because of these low thermal efficiencies. Total CO_2 emissions including indirect non-fuel-originated CO_2 emissions are estimated 355.8 g-C/kWh. Therefore, these aged coal-fired power plants if replaced with nuclear or natural gas ACC power plants will reduce CO_2 emissions significantly. In this study, we envisage a scenario in which aged coal-fired power plants operating in China in 1990 will be shut down

sequentially and replaced by Japanese LWR or natural gas ACC by using the CDM.

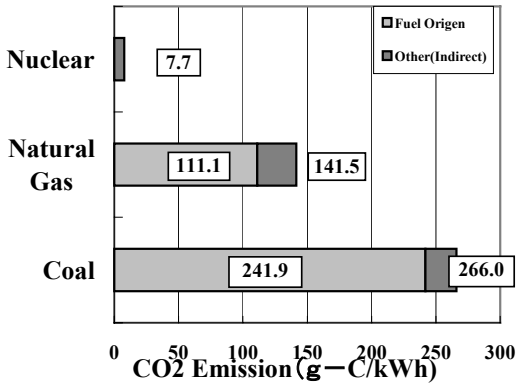

Fig.1. CO_2 Emission from power generating systems.

Some examples are available for predicting CO_2 emission right prices [3] [4], however results depend largely on the specific conditions, varying from 34 to 348 dollars/ton-C at the emission right prices in 2010 even in these two reports. The United States has now dropped out of the Kyoto Protocol, making it difficult to estimate the size of the future emission trading market, and to predict emission right prices. In the following study, we made calculations using a tentative price of 100 dollars/ton-C (27 dollars/ton- CO_2). The emission right price changes over time depending on the balance of supply and demand, however in this study it is assumed to be constant.

4. Funds procured by replacing Chinese aged coal-fired power plants

4.1 Reduction in CO_2 emissions by replacing plants and value of emission rights

(1) Replacement by LWR

Assuming that the plant availability factor is 80%, the annual (8,760 hours) average CO_2 emission per kW of electricity output (kWe) from aged coal-fired power plants in China is calculated as 2.49 ton-C. Correspondingly, the annual average CO_2 emission per kWe from an LWR in Japan is 0.04 ton-C.

This means that a 1,000 MWe equivalent aged Chinese coal-fired power plants if replaced with an LWR of the same electrical output will reduce CO_2 emissions by 2.44 million tons annually. The annual emission credit corresponding to the reduced CO_2 emission is 244 million dollars assuming 100 dollars/ton-C, which can be obtained throughout plant operations.

(2) Replacement by natural gas ACC

The same calculation when applied to natural gas ACC resulted in the reduction of 0.99 ton-C emission annually per kWe. This means that a 1,000 MWe equivalent aged Chinese coal-fired power plants if replaced by natural gas ACC operating at the same electrical output will reduce CO_2 by 1.5 million tons-C annually. As a result, the emission right value of 150 million dollars annually from replacement can be obtained throughout the plant operations.

4.2 Emission right values obtained from replacement by LWR

The emission right values obtained by operation of a 1,000 MWe LWR replaced with the same electrical output of the aged Chinese coal-fired power plants were calculated. The emission right values were determined as the amount equivalent to the values at the start of plant operations (present value), by discounting the total emission rights obtained after the start of plant operations, assuming that construction costs are paid at the start of plant operations. The discount rate has been discussed on many occasions, however in this study we employed 3%/year for reference, which was used as a typical value for estimating the back-end costs of nuclear power plants in Japan. We also used 1%/year and 5%/year as parameters for comparison.

Fig. 2 shows the relationship between the obtained emission right values and the plant operation period. For example , to acquire 3 billion dollars as the present value discounted at the start of plant operation would require about 15 years of the plant operation at the discount rate of 3%/year, about 13 years for 1%/year, and about 19 years for 5%/year.

If we assume the construction cost of the Japanese LWR to be 2,848 dollars/kWe [5], the period required to recover the construction cost of the Japanese LWR i.e. amount invested by Japan would be as shown in Fig. 3. Applying a discount rate of 3%/year, construction cost can be fully recovered by the emission rights alone when the plant has been operating for about 14 years. The periods required to recover construction cost are about 12 years at a discount rate of 1%/year and about 17 years at 5%/year.

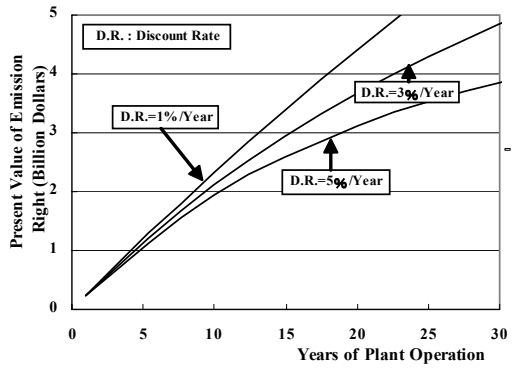

Fig.2. Present values of GHGs emission rights (Nuclear).

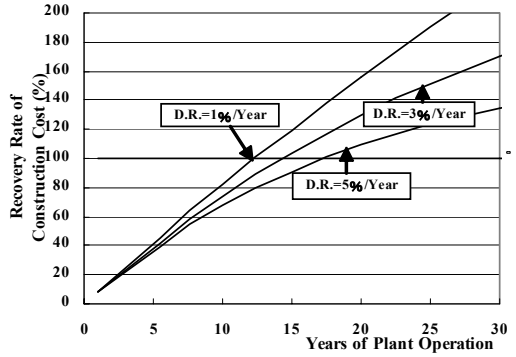

Fig.3. Plant operation period vs. construction cost recovery (Nuclear) .

4.3 Emission right values obtained from replacement by natural gas ACC

By doing the same calculations, Fig. 4 shows the relationship between the present values of the emission rights when replacing aged Chinese coal-fired power plants of 1,000 MWe equivalent with a natural gas ACC of the same electrical output, and the period of plant operation. The operating periods, for example, necessary to acquire 2 billion dollars as the present value discounted at the start of plant operation are about 17 years at a discount rate of 3%/year, about 14 years at 1%/year, and about 21 years at 5%/year.

Fig. 5 shows the relationship between the rate of recovery of the construction cost of a 1,000 MWe Japanese natural gas ACC plant when replaced with aged coal-fired power plants of the same electrical output, and the period of plant operation. In this case, the construction cost of the natural gas ACC plant was estimated as 1,703 dollars/kW [5]. The entire cost of construction would be recovered in about 14 years at a discount rate of 3%/year. The periods required to recover construction costs are about 12 years for a discount rate of 1%/year and about 17 years for 5%/year, almost equal to the LWR cases.

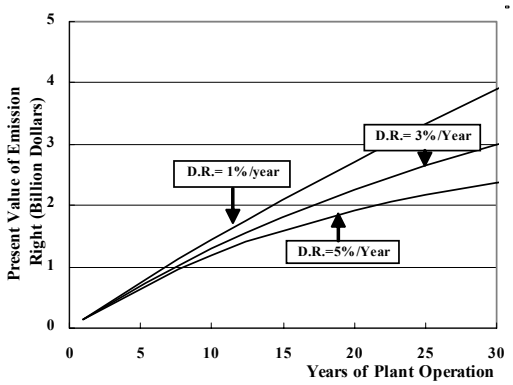

Fig.4. Present values of GHGs emission rights (Natural gas ACC).

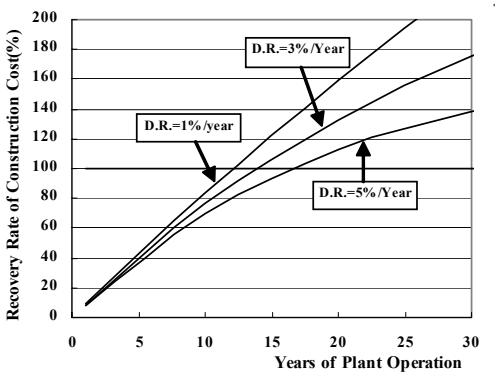

Fig.5. Plant operation period vs. construction cost recovery (Natural gas ACC).

4.4 Available emission right prices

Conversely, Fig. 6 shows the emission right prices obtained by the replacement with an LWR or a natural gas ACC at a discount rate of 3%/year. There is little difference between LWR and natural gas ACC cases. It is indicated that as the plants operate longer, the obtained emission right prices fall down rapidly. Operation for more than 14 years provides the emission right prices lower than 100 dollar/ton-C, and we may conclude that if the plants are operated for a certain time, it is available as an emission right trading business.

4.5 Comparison of expenses other than construction costs

Power plants need the operation and maintenance costs, and the fuel expenses. Prediction data for power generating costs [5] indicates that the operation and maintenance costs at Chinese plants due to come on line from 2005 to 2010 will be 0.58 cent/kWh for nuclear power plants and 0.55 cent/kWh for coal-fired power plants, i.e. not significantly different, however the fuel expenses are 0.78 cent/kWh for nuclear and 1.78 cent/kWh for coal. This suggests that utilizing nuclear power for the replacement plants would reduce fuel costs significantly.

No data predicting power generating costs of natural gas ACC in China has been reported. However data in reports on power generation costs in Japan shows that the operation and maintenance costs of natural gas ACC are slightly lower than those of nuclear or coal-fired power plant, however the demand of natural gas is predicted to grow worldwide, causing large escalation in the fuel prices. This suggests that nuclear power has larger impact on reducing the fuel expenses.

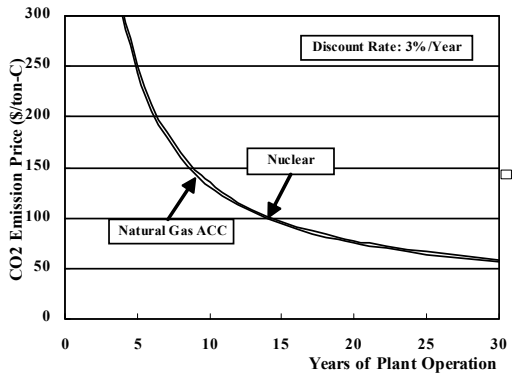

Fig.6 Available emission right prices.

5. Conclusions

Introduction of advanced power plants such as LWR or natural gas ACC is a practical means of concurrently resolving both the electricity shortage and the environmental issues faced by China, however funds raising for plant constructions are major issue. As a solution, we estimated the effectiveness of applying the CDM, one of the Kyoto mechanisms. As a result, we found that the greenhouse gases emission rights obtained from the replacement of aged Chinese coal-fired power plants with advanced Japanese power plants have the following features;

(1) The construction costs of the replaced advanced power plants can be recovered in about 14 years (at a discount rate of 3%/year), indicating little difference in recovery time of construction costs between LWR and natural gas ACC, and

(2) The longer the plant is operated, the lower the emission right prices are obtained. This suggests large potential for an emission right trading business.

To apply this practically, it will be necessary to clarify that nuclear power, not authorized for the CDM at present, is useful for both developing and developed countries, and an international approach is needed to recognize the eligibility of nuclear power at future COPs. Negative arguments regarding nuclear power to date at the COPs can be largely attributed to domination of the conferences by European environmentalists, however are also due to a lack of awareness on the part of developing countries. Many developing countries hope to use nuclear power but do not understand the significance of nuclear power in the CDM, meaning few delegates from developing countries support nuclear power at the conferences.

At future COPs, actions aimed at the second commitment period will be vital. This means that nuclear power should be positioned as a reasonable step for reducing the greenhouse gases as part of the JI and the CDM, to solve global environmental issues in the developing countries of Asia, and to enhance their energy security. For this reason, we need to explain the significance of nuclear power to the developing countries as interested parties in the CDM, and persuade them to work with us for a revival of the nuclear power at the COPs.

References and Notes

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