Global Warming Abatement and Coal Supply and Demand [1]

Yoshimitsu MIMUROTO, Deputy General Manager
Koichi KOIZUMI, Senior Engineer
International Cooperation Department

Introduction

In 2001, Japan's primary energy supply slipped by 0.3% from the previous year. By energy source, coal was up 4.7%, LNG up 3.7%, oil was down 2.8% and nuclear down 8.7%. While the growth of coal was most conspicuous, coal supply in 2001 had already reached 151 million tons coal equivalent (tce), which was identical to the level for 2010 assumed in the target case by the Advisory Committee for Resources and Energy in its energy outlook revealed in July 2001. In view of the fact that coal demand is predicted to continue increasing, particularly for coal-fired power generation, intensified decoupling from the target case (designed to meet the Kyoto target) appears very likely.

Under these circumstances, CO_2 emissions originating from coal are expected to increase along with growing coal consumption, while at the same time, from the viewpoint of global environmental preservation, stepped-up CO_2 reduction efforts will become imperative. In institutional terms, CO_2 reduction measures can be roughly divided into domestic actions, typically carbon/environmental taxes, and global responses represented by the Kyoto Mechanism. This paper provides an analysis of the impacts that domestic measures and the Kyoto Mechanism can have on coal supply and demand.

1. Japan's Coal Supply and Demand: Present Situation and Outlook

1-1 Present situation of coal supply and demand

Japan's total primary energy supply, which was 459 million tons oil equivalent (toe) in 1990, reached 546 million toe in 2001, indicating an increase of 1.6%/year for the period. Of this, coal increased from 79 million toe in 1990 to 106 million toe in 2001, up 2.7%/year, a rate much faster than the growth of primary energy. The primary energy mix in 2001 showed oil accounting for 50%, coal 19%, LNG 13%, nuclear 12% and others 6%. Coal has thus become the second most important source of Japan's energy supply after oil.

In FY1980, Japan's coal demand totalled 93 million tons, of which 71% was coking

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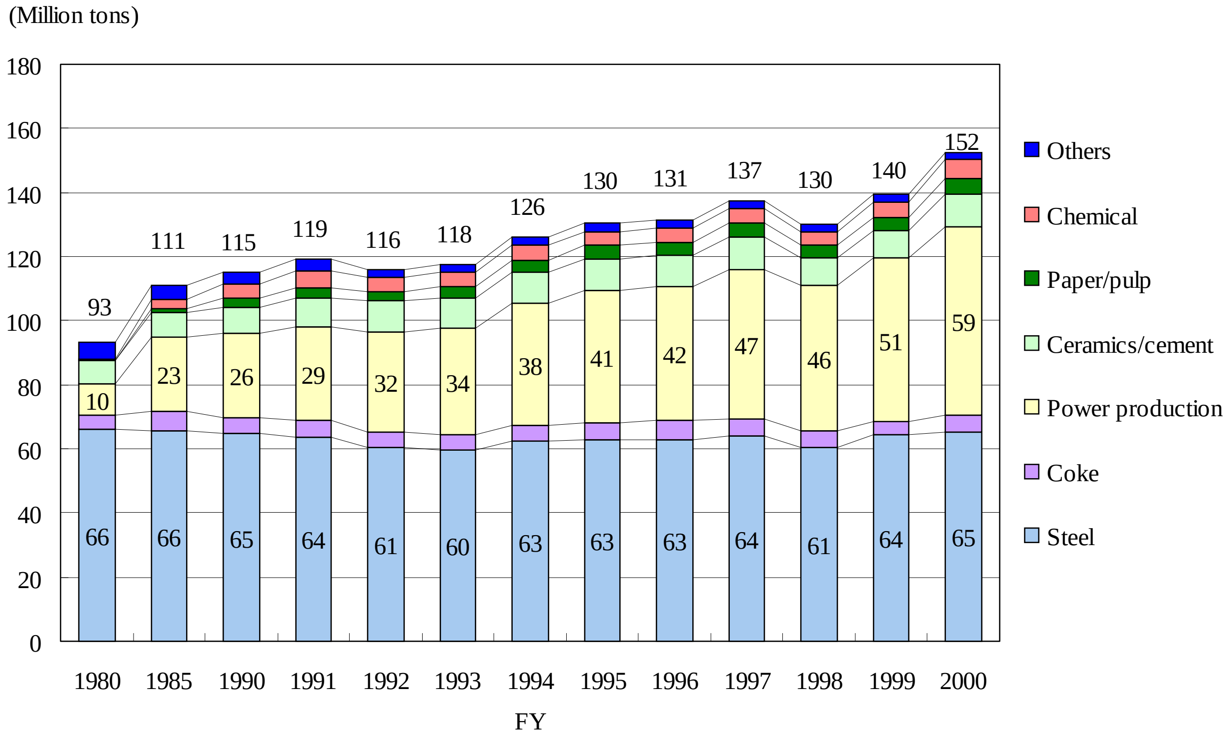
[1] This study report was recomposed from "FY2001 Works to Advanced Overseas Coal Development (Coal Supply and Demand Viewed from Energy Security and Global Warming Abatement Aspects)," a study project awarded to IEEJ by the New Energy and Industrial Development Organization. Acknowledgments are due to the NEDO for their kind permission for this publication.

coal used in steelmaking. Since then, coking coal demand has remained flat or has been slightly on the decline. By contrast, as a result of the two oil crises, steaming coal demand — mainly from the power industry — has been growing steadily (Fig. 1-1). By FY1984 coal demand had surpassed 100 million tons and, in FY1997, steaming coal exceeded coking coal in terms of demand size. It also appears likely that in the near future, the coal demand of the power industry will become larger than that of the steel industry.

Fig. 1-1 Coal Demand by Industry



Source: Prepared by IEEJ on the basis of "FY2000 Energy Production and Demand Statistical Yearbook."

1-2 Advisory Committee for Resources, and Energy-related Outlook and Tasks

Table 1-1 shows the latest long-term energy supply outlook published in July 2001 by the Advisory Committee for Resources and Energy (ACRE). This states that, by FY 2010, the total primary energy supply, which was 593 million kl crude oil equivalent in FY1999, will increase to 622 million kl in the base case and 602 million kl in the target case. Of this, coal supply in FY2010 is projected to be 136 million kl crude oil equivalent in the base case and 114 million kl in the target case, up from 103 million kl in FY1999. These figures have been revised considerably upward from the previous outlook published in 1998, in which the coal supply was forecast to be 107 million kl in the base case and 92 million kl in the target case. These changes can be attributed largely to the downward revision of nuclear figures in the latest outlook. Namely, instead of the ambitious introduction of nuclear energy assumed for the years up to 2010 in the previous outlook, more realistic figures are employed in the latest outlook based on a pragmatic long-term power development plan.

Table 1-1 Outlook by the Advisory Committee for Resources and Energy

(unit: million kiloliter of crude oil equivalent)

Item \ FY	1990		1999		2010			
					Standard case		Target case	
Total Primary Energy Supply	526		593		622		Around 602	
Form of Energy	Quantity	Shares %	Quantity	Shares %	Quantity	Shares %	Quantity	Shares %
Oil	307	58.3	308	52.0	280	45.0	Around 271	Around 45
Coal	87	16.6	103	17.4	136	21.9	Around 114	Around 19
Natural gas	53	10.1	75	12.7	82	13.2	Around 83	Around 14
Nuclear	49	9.4	77	13.0	93	15.0	93	Around 15
Hydro	22	4.2	21	3.6	20	3.2	20	Around 3
Geothermal	1	0.1	1	0.2	1	0.2	1	Around 0.2
New energies/others	7	1.3	7	1.1	10	1.6	20	Around 3
Renewables	29	5.6	29	4.9	30	4.8	40	Around 7
Final energy consumption	349		402		409		Around 400	

Note: the figures for the renewables include new energies, hydro and geothermal.

Source: Prepared by IEEJ based on "Energy Policy from Now On," a report prepared jointly by the General and the Supply & Demand Subcommittees, the Advisory Committee for Resources and Energy.

If calculated in terms of tons coal equivalent (tce), coal supply assumed for FY2010 in the latest outlook turns out to be 180 million tce in the base case and 151 million tce in the target case. While the latest outlook was prepared using the 136-million-tce coal supply in FY1999 as actual records, the coal supply in 2001 (calendar year) had already reached 151 million tce, which is identical to the assumed level for 2010 in the target case.

According to the FY2001 edition of "Outline of Electricity Supply Plan," installed coal-fired capacities, which were 29.22 GW (12.8% of the whole) at the end of FY2000, will reach 44.13 GW (16.2%) by the end of FY2010. As a result, coal requirements will increase to 72.54 million tons by FY2005 (up 13.60 million tons over FY2000), and to 70.65 million tons (up 11.71 million tons over FY2000) (Table 1-2). Given these actual records and the greater coal demand expected from coal-fired power plants, coal supply in FY2010 is unlikely to remain at 151 million tce.

Table 1-2 Planned Installed Capacities and Generated Output by Source

FY2000 yearend	Installed capacity		Generated output		Utilization factor	Fuel needs 10,000t 10,000kl
	10 MW	Share	TWh	Share		
Hydro	4,478	19.5%	90.5	9.6%	2.3%	-
Nuclear	4,492	19.6%	319.7	34.0%	8.1%	-
Coal	2,922	12.8%	168.1	17.9%	6.6%	5,893.7
LNG	5,722	25.0%	249.1	26.5%	5.0%	3,944.4
Oil	4,839	21.1%	93.5	9.9%	2.2%	2,611.6
New energies/others	460	2.0%	19.6	2.1%	4.9%	-
Total	22,913	100.0%	940.5	100.0%	4.7%	
FY2005 yearend	Installed capacity		Generated output		Utilization factor	Fuel needs 10,000t 10,000kl
	10 MW	Share	TWh	Share		
Hydro	4,568	18.6%	96.9	9.6%	2.4%	-
Nuclear	4,958	20.2%	354.7	35.1%	8.2%	-
Coal	3,975	16.2%	206.9	20.5%	5.9%	7,254.0
LNG	5,888	24.0%	238.8	23.6%	4.6%	3,781.3
Oil	4,731	19.3%	87.4	8.7%	2.1%	2,441.2
New energies/others	435	1.8%	25.8	2.5%	6.8%	-
Total	24,555	100.0%	1,010.5	100.0%	4.7%	
FY2010 yearend	Installed capacity		Generated output		Utilization factor	Fuel needs 10,000t 10,000kl
	10 MW	Share	TWh	Share		
Hydro	4,810	17.7%	99.3	9.1%	2.4%	-
Nuclear	6,185	22.7%	433.4	39.8%	8.0%	-
Coal	4,413	16.2%	201.5	18.5%	5.2%	7,064.7
LNG	6,696	24.6%	250.2	23.0%	4.3%	3,961.8
Oil	4,694	17.2%	79.2	7.3%	1.9%	2,212.2
New energies/others	431	1.6%	25.7	2.4%	6.8%	-
Total	27,229	100.0%	1,089.3	100.0%	4.6%	

Note: the figures for generated output and fuel needs in FY2000 are estimated actual records.
Source: Prepared by IEEJ on the basis of “Outline of FY2001 Electricity Supply Plan.”

Regarding the latest outlook released by the ACRE, the two points mentioned below may be considered debatable. There is a strong likelihood that the shapes of energy and CO_2 reductions assumed in the outlook will in reality prove to be quite different.

(1) In view of the virtual certainty of very ambitious energy conservation, the base case cannot be regarded as the so-called “business-as-usual” case.

(2) According to the outlook, final energy consumption should be kept more or less flat, or up a mere 0.16%/year in the base case and down 0.05%/year in the target case even when the GDP grows 2%/year in real terms in the period FY1999-2010 (Table 1-1). This means a decoupling between the economic growth and energy consumption. While it is true that such a phenomenon did occur during the oil crises in the 1970s, it has never taken place in normal times. A realization of the CO_2 reductions assumed in the outlook would require such thorough conservation efforts that real suffering would be inflicted on the public, including drastic changes in lifestyle.

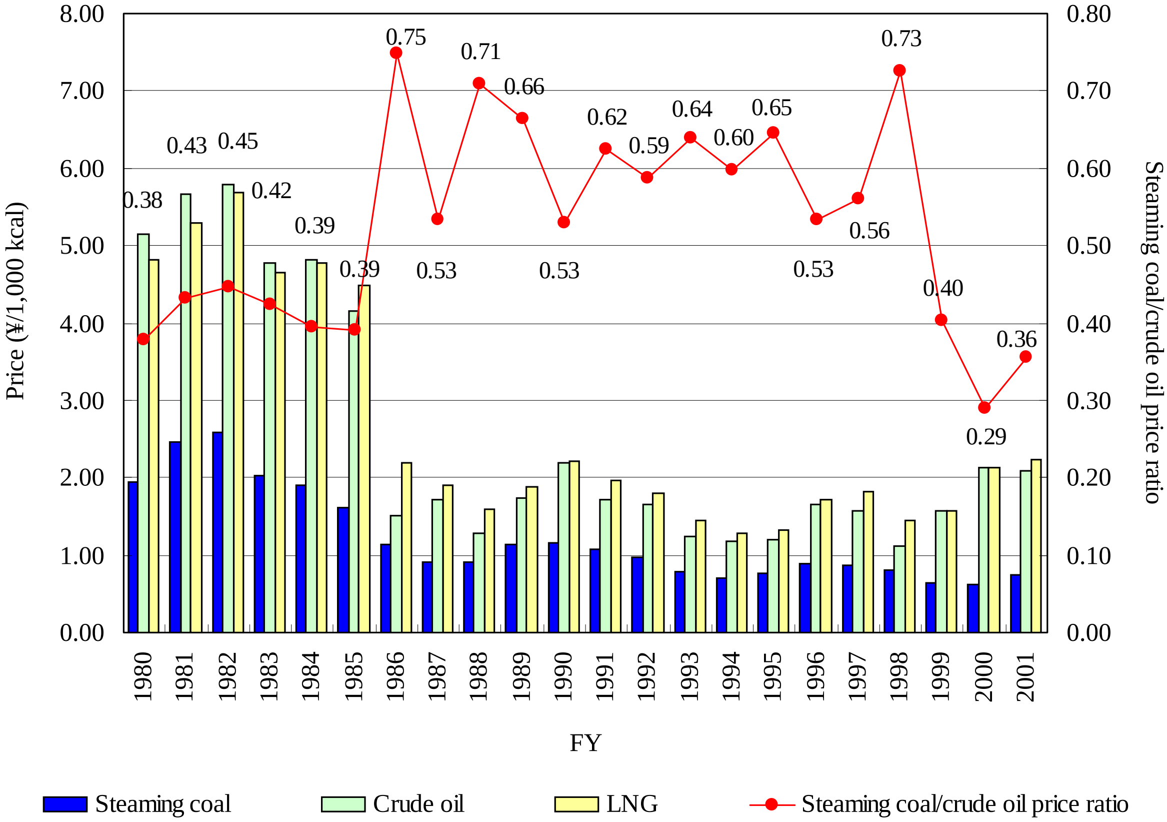
2. Economic Advantage of Coal-fired Power

2-1 Price advantage of coal over oil

The situation of Japan's steaming coal demand revived when the oil price skyrocketed following the two oil crises, and the greatest single contributor to the revival was the cheaper price of coal as compared to the spiraling prices of oil and gas. Given that coal is disadvantageous in points such as handling and environmental load, the utility of coal blurs unless its greatest strength — its cheapness — can be demonstrated. In this context, the ceiling price of coal depends on the oil price. Today, the ceiling price is falling below the level of the first half of the 1980, while the coal price for its part is getting cheaper thanks to productivity gains, etc.

As shown in Fig. 2-1, in terms of CIF in Japan per unit calorific value (1,000 kcal), the coal price has followed the very same trends as those of the oil price. However, the coal price has always remained cheaper, less volatile and more constant than the crude oil price. Particularly during the first half of the 1980s, the price advantage of coal over crude oil stayed high. Namely, up to 1984, the ratio of the steaming coal price to the crude oil price remained extremely limited within 0.38-0.45. In 1986, however, when the oil price collapsed, the ratio shot up to 0.75. In the subsequent years up to 1998, the ratio stayed within 0.53-0.73. As from 1999-2000, the coal price remained relatively stable despite the crude oil price spike, and the ratio stayed low at 0.29-0.40. The upper limit of the ratio of the coal price to the crude oil price can be put at around 75% on a basis of calorific value.

Fig. 2-1 Relations between Crude Oil and Coal Prices, CIF in Japan



Note: Data on 2001 are on a calendar year basis. The figures on the plotted line graph represent the steaming coal/crude oil price ratio.

Source: prepared by IEEJ on the basis of the Ministry of Finance, “Japanese Trade Monthly Reports.”

2-2 Advantage of coal as a power source

Table 2-1 shows the generating costs of representative power sources, including coal-fired, oil-fired, LNG-fired, nuclear and hydro.

The source having the lowest generating cost at ¥5.86/kWh is nuclear, followed by LNG-fired at ¥6.42/kWh, coal-fired at ¥6.46/kWh, oil-fired at ¥10.16/kWh, and hydro at ¥13.63/kWh, in that order. Nuclear has such a cheap generating cost (particularly operating cost) that its economic advantage can be best demonstrated when it is put into service as the baseload source to the greatest extent possible. The high generating cost of hydro reflects the huge initial investment costs, while its operating cost is extremely low.

In terms of economics of operation, nuclear is the most advantageous, followed by existing hydro and fossil-fired power generation in that order. Among fossil-fired power, coal- and LNG-fired facilities have roughly the same cost advantage, while oil-fired power costs more than either of them and can never be competitive with them. According to the calculation results shown in Table 2-1, coal-fired power generation costs ¥0.04/kWh more than LNG-fired. The advantage of LNG-fired to coal-fired can be reversed for the reasons mentioned below.

Table 2-1 Generating Costs by Power Source

Power source		Coal-fired	LNG-fired	Oil-fired	Nuclear	Hydro
Generating cost (¥/kWh)		6.46	6.42	10.16	5.86	13.63
Assumptions	Output (10 MW)	90	150	40	130	1.5
	Number of years in operation (years)	40	40	40	40	40
	Utilization factor (%)	80	80	80	80	45
	Fuel price*1	38.8 ($/t)	18,902(¥/t)	13.13($/bbl)		
	Rate of fuel price increase*2	0.88 (%/y)	1.82 (%/y)	3.36 (%/y)		
	Exchange rate: 128.02 (average in FY1998)					

(*1) Average in FY1998

(*2) Calculated from the forecast values for 2015-2020 in the IEA, "World Energy Outlook" and the average in FY1998.

Source: Prepared by IEEJ on the basis of the reference materials of the Nuclear Subcommittee, the Advisory Committee for Resources and Energy (December 16, 1999).

(1) As clearly noted from Fig. 2-1, coal is always priced cheaper than LNG per 1,000 kcal, but in FY1998, the year for which the costs were calculated, the differentials between coal and LNG were narrower than in ordinary years. The average coal price per 1,000 kcal, equivalent to 48% of the LNG price in 1981-2001, stood at 56% in 1998.

(2) The costs were calculated by assuming the utilization factor at 80% for both coal- and LNG-fired, which was quite different from actual operation. Coal-fired, mainly used in the baseload operation, records a higher utilization factor than LNG-fired in service as a middle- and peak-load source. Actual records for FY2000 reveal that coal-fired generation, running at 65.7%, surpassed LNG-fired (49.7%) by 16% (Table 2-1). The cost calculations include sensitivity analyses made by varying the utilization factor. The generating cost of LNG-fired generation turns out to be ¥6.78/kWh when the utilization factor stands at 70%, and ¥7.27/kWh when this is 60%, which are higher than coal-fired (utilization factor: 80%) (Table 2-2).

Table 2-2 Utilization Factors vs. Generating Costs

	Utilization factor	Generating cost (¥/kWh)
Oil-fired	30 %	16.11
	70 %	10.67
	80 %	10.16
LNG-fired	60 %	7.27
	70 %	6.78
	80 %	6.42
Coal-fired	70 %	7.00
	80 %	6.46

Source: Prepared by IEEJ on the basis of the reference materials of the Nuclear Subcommittee, the Advisory Committee for Resources and Energy (December 16, 1999).

(3) As in the economics of hydro, the fuel cost of existing coal-fired facilities is cheap. For this reason, putting not LNG- but coal-fired generation in service as the maximum load can result in a lower cash disbursement while running, in which depreciation is not taken into account (because cash disbursement in the form of equipment investment has already been incurred). In short, it is advantageous in terms of cash flow.

(4) In its 2001 July report, the ACRE revealed the following scenario of cost calculation: "…..a measure expected to be effective in promoting fuel switching to natural gas by broadening the range in which the total generating cost of natural gas is cheaper than that of coal: to raise the total generating cost of coal by about ¥0.3/kWh in relative terms to that of natural gas." In short, this suggests that the cost of coal-fired is cheaper.

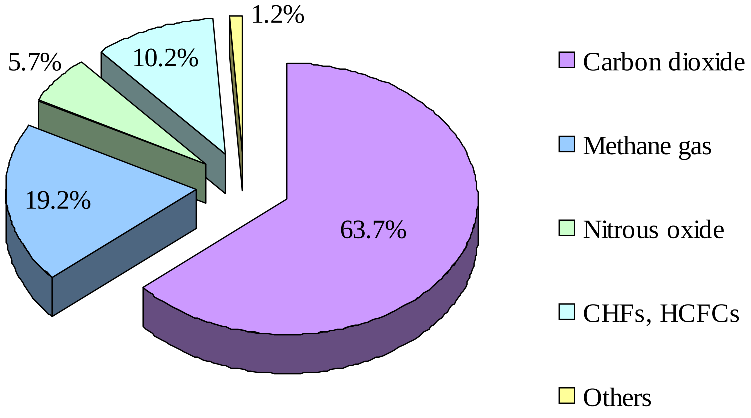
For these reasons, as far as past records are concerned, coal-fired is generally found to be advantageous to LNG-fired generation in economic terms.

3. GHG/CO_2 Emissions: Present Situation and Outlook

3-1 GHG/CO_2 emissions worldwide

Degrees of contribution to global warming vary depending on the types of greenhouse gases (GHGs). However, judging from the emissions in recent years, carbon dioxide (CO_2) is reportedly responsible for over 60% of GHG contributions. For example, a document of the IPCC (Intergovernmental Panel on Climate Change) provided a summary of which GHGs had contributed to global warming, and to what extent, in 1992, as illustrated in Fig. 3-1. While man-made CO_2 results largely from fossil fuel production/use and cement production, fossil fuels-derived CO_2 occupies the predominant portion. For this reason, we will base our discussions below on the assumption that all man-made CO_2 emissions = CO_2 emissions originating from fossil fuels.

Fig. 3-1 Degrees of Contribution to Warming by GHG (1992)



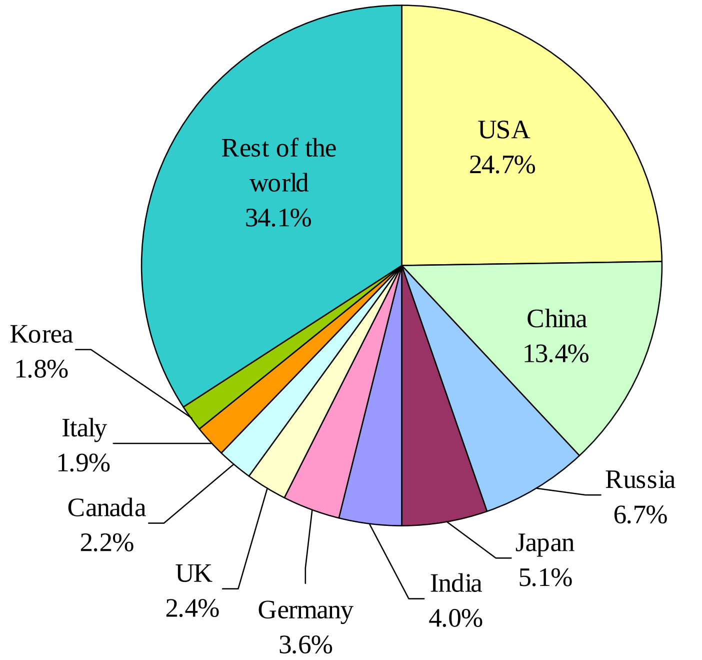
Source: Prepared by IEEJ on the basis of IPCC data.

The world's CO_2 emissions originating from fossil fuels — 3,917 million t-C (tons carbon equivalent) in 1971 — steadily increased to 5,003 million t-C in 1980, 5,732 million t-C in 1990 and 6,234 million t-C in 1999 along with the strong growth of fossil fuel demand. By region, the average growth from 1990 to 1999 was highest in the Middle East at 4.6%, followed by Latin America (3.3%) and Asia (3.1%). Emissions in Europe fell by 2.2%. In absolute terms, CO_2 emissions in 1999 were largest in Asia at 1,876 million t-C, followed by Europe (1,790 million t-C) and the U.S. (1,678 million t-C). The Middle East, which recorded the highest growth, produced 248 million t-C of CO_2.

By country, the U.S. and China were responsible for by far the largest portions of the world's CO_2 emissions in 1999 at 24.7% and 13.4%, respectively, followed by Russia (6.7%) and Japan (5.1%). When combined, these four countries alone produced half of the world's CO_2 emissions. They are followed by India, Germany, the U.K. and Canada (Fig. 3-2). For global reduction of CO_2 emissions, U.S. participation is crucial. In this context, the decision of the U.S., the world's largest CO_2 producer, to walk out from the Kyoto Protocol has serious impacts.

During the period from 1990 to 1999, the world's CO_2 emissions grew by 8.8%. By region, CO_2 emissions were up 15.3% in the U.S., down 1.3% in OECD Europe, down 35.3% in non-OECD Europe, up 24.8% in China, and up 10.2% in Japan (Table 3-1). It is worth noting that, in all Asian countries with the exceptions of China and Japan, CO_2 emissions rose by as much as 56.7% over the same period.

Fig. 3-2 CO_2 Emissions Mix in 1999 by Major Country



Source: "Energy/Economy Statistical Handbook 2002 Edition" edited by EDMC, IEEJ

By type of fossil fuel, the world's CO_2 emissions in 1999 can be broken down as illustrated in Fig. 3-3. Oil- and coal-origin CO_2 emissions held virtually identical shares (oil 39.8%, coal 39.5%), while gas-origin emissions accounted for 20.7%.

Table 3-1 CO_2 Emissions and Growth by Major Country

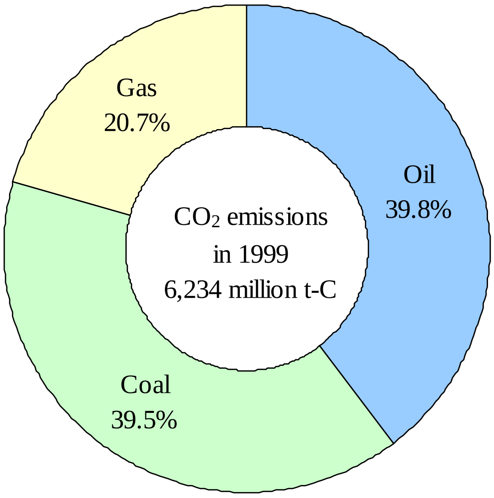
(Unit: Million t-C)

	1990	1999	Growth rate
USA	1,338	1,542	15.3%
Europe OECD	1,102	1,087	-1.3%
Europe non-OECD	1,086	703	-35.3%
China	668	834	24.8%
Japan (Note)	290	320	10.2%
Rest of Asia	461	722	56.7%
Rest of the world	788	1,025	30.2%
World total	5,732	6,234	8.8%
EU-15 total	872	871	-0.1%

Note: these figures, calculated in reference to IEA data, do not accord with the calculations made by the Japanese government.

Source: "Energy/Economy Statistical Handbook 2002 Edition" edited by EDMC, IEEJ

Fig. 3-3 World's CO_2 Emissions Mix by Energy Source (1999)



Source: "Energy/Economy Statistical Handbook 2002 Edition" edited by EDMC, IEEJ

3-2 GHG/CO_2 emissions in Japan

The Ministry of the Environment in its report, "Greenhouse Gas Emissions in FY1999," calculated the total GHG emissions in FY1999 (by adding up individual GHG emissions multiplied by GWP[2]). The result was 1,307 million t-CO_2 (carbon dioxide equivalent), up by about 6.8% over the emissions (1,224 million t-CO_2) in the base year (1990) under the Kyoto Protocol (although the base year for HFCs, PFCs and SF6 is 1995 [3]). It should be noted that, because some of the data (on wastes, etc.) used in the calculation were, for example, FY1997 data due to statistical limits, the estimated total emissions are provisional and can be revised in the future.

In Japan's GHG emissions, CO_2 accounts for 94%, which is far higher than the CO_2 share in the world's total. Thus, the undisputed share held by CO_2 of fossil-fuels origin is a conspicuous characteristic of Japan's GHG emissions. As a result of the sluggish fossil fuel demand after the two oil crises, CO_2 emissions of fossil-fuels origin leveled off at 250 million t-C or so in the first half of the 1980s. However, in the second half of the decade, CO_2 emissions again started growing as a result of the economic recovery. The emissions totalled 287 million t-C in FY1990, the base year taken by the Kyoto Protocol. They surpassed 300

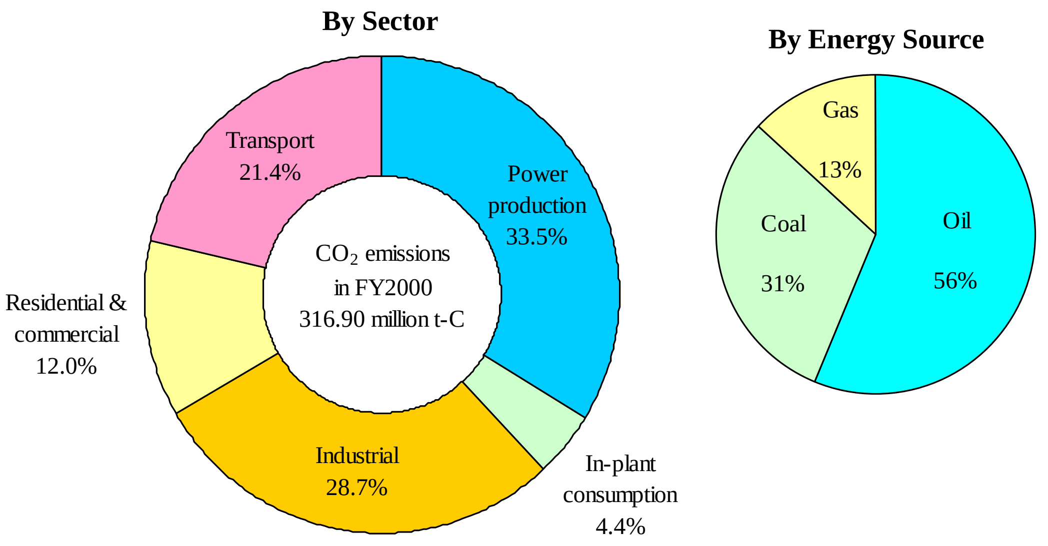
[2] Global warming potential (GWP) is a coefficient that expresses the degree of greenhouse effect produced by GHGs in terms of the ratio of CO_2 to the said degree. The numerical data were obtained from the Second Assessment Report (1995) of the IPPC.

[3] Article 3 – 8 of the Kyoto Protocol provides that the three types of GHGs, including HFCs, can be calculated by taking 1995 as the base year. Also, while the Kyoto Protocol specifies "calendar year," the values for energy-origin CO_2, etc. are taken here from "fiscal year" (from April to March) because of statistical limits.

million t-C in FY1994 and reached 317 million t-C in FY2000.

Fig. 3-4 shows Japan's CO_2 emissions by sector and fossil fuel. By sector, power production registered the largest emissions and accounted for 38% of the total with in-plant power production included. The sectors following this are industrial at 29%, transport 21% and residential & commercial 12%, in that order. By fuel, CO_2 emissions originating from oil are the largest accounting for 56% of the whole, followed by 31% for emissions of coal origin and 13% of gas origin. Larger emissions of oil origin and smaller emissions of gas origin than the world average are characteristic of Japan's CO_2 emissions.

Fig. 3-4 Japan's CO_2 Emissions Mix (FY2000)



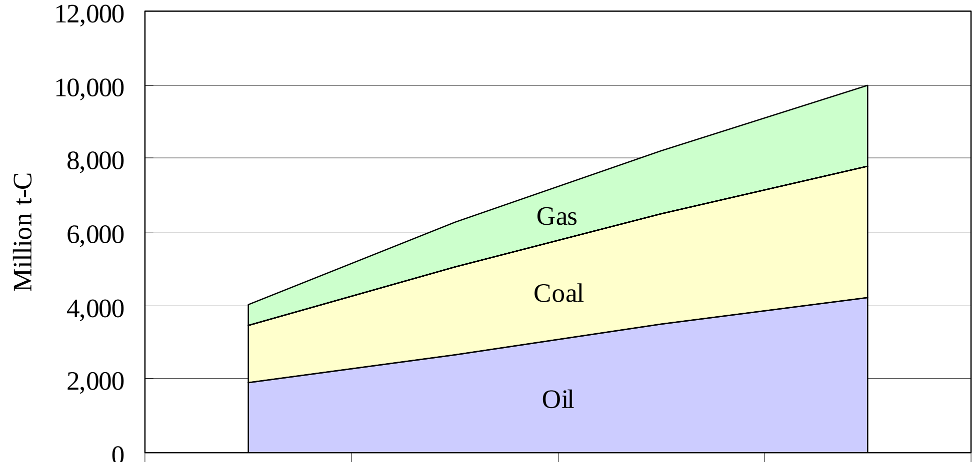
Source: "Energy/Economy Statistical Handbook 2002 Edition" edited by EDMC, IEEJ

3-3 World's CO_2 emissions outlook

3-3-1 IEA, "World Energy Outlook 2000"

The IEA predicts in its "World Energy Outlook 2000" that CO_2 emissions resulting from fossil fuels will grow by 2.1%/year from 1997 to 2020, and will reach 8,204 million t-C by 2010 and 10,004 million t-C by 2020 (Fig. 3-5). Looking at the growth of CO_2 emissions by fuel over this period, coal is projected to go up 1.8%, oil up 2.0%, and gas, the highest, up 2.7%, on a yearly basis. In absolute terms, CO_2 emissions will be in the order of oil > coal > gas. This order will remain unchanged even as of 2020.

Fig. 3-5 World's CO_2 Emissions Forecast by Energy Source



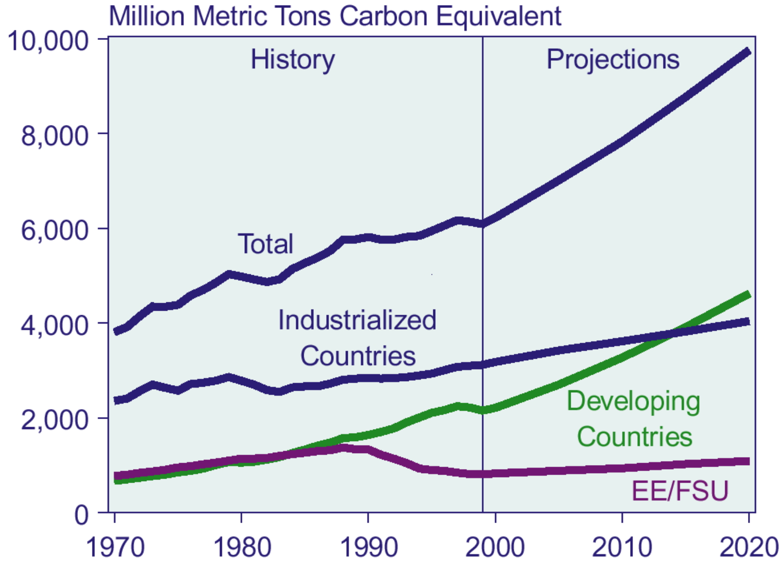
	1971	1997	2010	2020
Gas	571	1,205	1,716	2,236
Coal	1,541	2,389	2,998	3,568
Oil	1,911	2,674	3,490	4,199
Total	4,024	6,268	8,204	10,004

Source: IEA, "World Energy Outlook 2000"

3-3-2 USDOE, EIA, "International Energy Outlook 2001"

The EIA of the USDOE states in its "International Energy Outlook 2001" that CO_2 emissions will increase from 5,800 million t-C in 1990 to 7,800 million t-C by 2010, and 9,800 million t-C by 2020—figures that are more conservative than those projected in the "World Energy Outlook 2000" (Fig. 3-6). The EIA states that almost all of the incremental CO_2 emissions come from the developing world, where massive energy consumption is likely as a result of emerging economies. The share of the developing countries in incremental CO_2 emissions is put at 81% in the period 1990–2010 and at 76% in 1990–2020. If developing countries remain heavily dependent on coal and other fossil fuels as projected, the world's CO_2 emissions are likely to surpass the projected range considerably even though the industrialized world has initiated CO_2 reduction efforts.

Fig. 3-6 CO_2 Emissions Outlook by Region



Source: EIA, "International Energy Outlook 2001"

3-4 Japan's CO_2 emissions outlook

Table 3-2 shows the outlook for Japan's CO_2 emissions, which is based on the ACRE latest energy supply and demand outlook (July 2001). The base case puts the emissions in 2010 at 370 million t-C, 6.9% larger than FY1990 records. Thus, if the Kyoto target is to be met, Japan will have to cut its CO_2 emissions by 20 million t-C.

Table 3-2 Japan's CO_2 Emissions Outlook

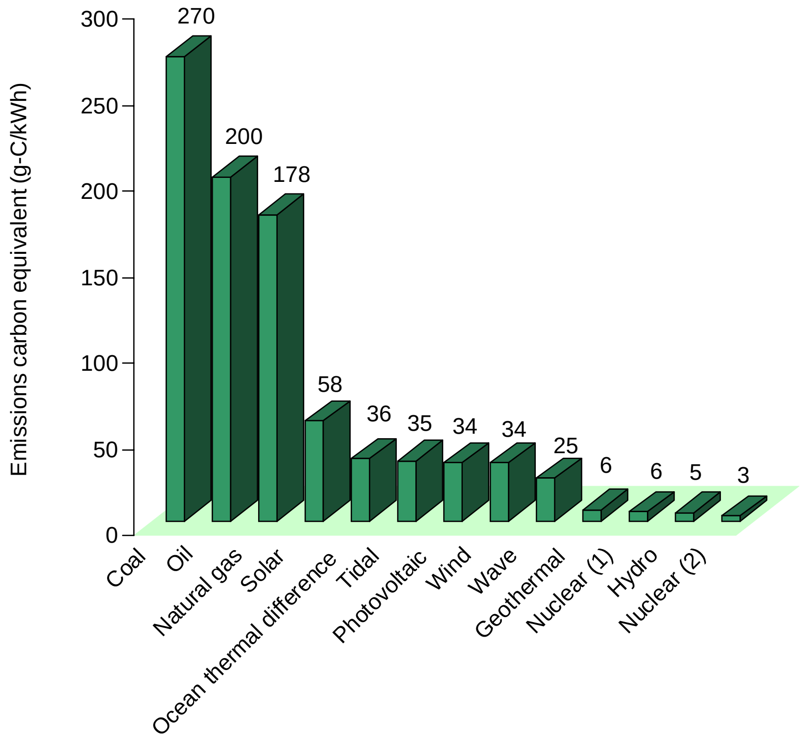
FY	1990	1999	2010	
	Actual	Actual	Base case	Target case
Primary energy supply (million kl crude oil equivalent	526	593	622	Around 602
CO_2 emissions (million t-C) (Growth over FY1990)	287	313 (8.9%)	307 (6.9%)	Around 287

Source: The Advisory Committee for Resources and Energy's report (July 2001)

3-5 CO_2 intensity

Comparing CO_2 intensity by fuel, coal is the most CO_2-intensive, amounting to 1.0422 t-C/toe of steaming coal (indigenous). Likewise, oil is as CO_2-intensive as 0.7811 t-C/toe, and LNG 0.5639 t-C/toe. The CO_2 intensity of power source per kWh, shown in Fig. 3-7, reveals that coal-fired power is by far the most CO_2-intensive.

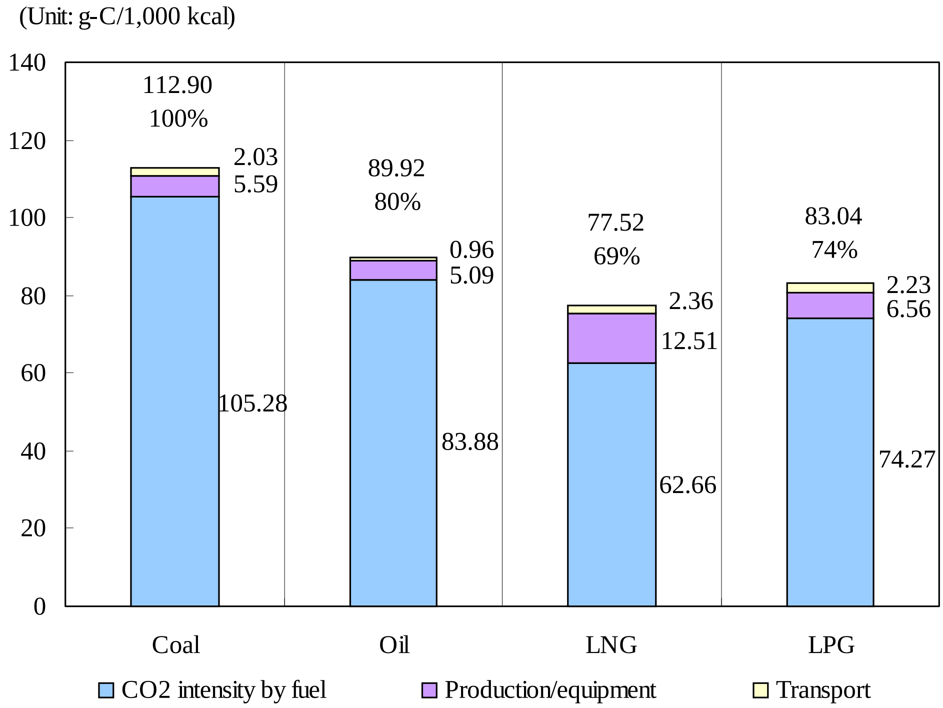
Fig. 3-7 CO_2 Emissions per kWh by Power Source



Source: The Central Research Institute of Electric Power Industry (March 1995)

While fossil fuels naturally produce CO_2 while burning, they also emit CO_2 at each stage of their production, storage and transportation. Accordingly, when evaluating CO_2 emissions inherent to each fuel, it is essential to cover the entire cycle of the fuel from production to final consumption. Fig. 3-8 shows the CO_2 loads of individual fossil fuels, which were calculated pursuant to ISO14040 specified by the ISO (International Organization for Standardization) by covering the full range from production to transportation and consumption of Japan's imported energies (coal, oil, LPG and LNG). The coal-LNG ratio of CO_2 load, which is 100:60 when focusing on the fuel stage alone, drops to 100:69 when assessed in total cycle terms. This is explained by fuel consumption in the LNG production and liquefaction processes, flaring, and fairly massive leaks of methane gas (CH4) resulting from vents. While Japan's calculation of CO_2 emissions centers on CO_2 resulting from fuel burning, life cycle-based calculations are essential if CO_2 emissions are to be determined from a global viewpoint.

Fig. 3-8 Environmental Loads of Fossil Energies
(CO_2 Intensity: Net Calorific Value Basis)



Note: The figures in % at the top of the graphs show relative environmental loads inherent to each fossil energy when CO_2 intensity of coal is taken as 100%.
Source: IEEJ, Regular Study Briefing, “A Life Cycle Inventory Analysis of Japan’s Fossil Energies” (May 1999)

4. CO_2 Reductions

4-1 US walkout from the Kyoto Protocol and inherent risks for the protocol

In March 2001, the U.S. announced its decision to walk out from the Kyoto Protocol. Why do the Bush administration and U.S. industry oppose the Kyoto Protocol, and in what points do they question the protocol? Answers to these questions are given by the National Petroleum Foundation, known as a spokesman for the oil majors, in its recent report entitled “If Kyoto Protocol Is Damned, What’s Next?” The answers are summarized below:

(1) The specified greenhouse gas (GHG) reduction targets are too unrealistic and impose a formidable cost burden that is unacceptable for the U.S. economy. Particularly disadvantageous for the U.S. is the fact that the base year taken under the Kyoto Protocol is 1990, a year of recession in the U.S. According to the “International Energy Outlook” released by the U.S. Department of Energy in March this year, U.S. CO_2 emissions, which as of 1999 were already 12% above the 1990 levels, are projected to

increase to 34% by 2010. By contrast, the EU, whose emissions were up 1% as of 1999, is expected to remain at the 12% increase level as of 2010.

(2) The protocol imposes no obligation of GHG reductions on developing countries, and neither does it provide any arrangements for curbing emissions from 2008–2012 onward. However, GHG emissions by developing countries are likely to nearly double in the period 1990–2010. In particular, emissions from China are expected to outstrip those from the EU by 2010. In order to meet the Kyoto target, the U.S. would have to cut its CO_2 emissions by as much as 40% by 2010. The resultant colossal cost burden would unfairly damage the international competitiveness of the U.S. industry against developing countries.

(3) The only possibility for meeting the Kyoto target will be to put the “Kyoto Mechanism” to maximum use, but the question of how to operate this system has aroused heated debates without yielding any specific rules to date. An additional problem is that, under this system, a few billion dollars of funds will be transferred every year from U.S. firms to Russia. Russia does not need to spend a single dollar in GHG reductions, simply because 1990 happened to be taken as the base year.

(4) The recent turmoil in California has discouraged Americans from having high hopes for emissions trading. This is because, even though the U.S. certainly had success in SOx emissions trading, the NOx trading system in California failed to function when a power shortage led to mounting fossil-fired power generation—which, in turn, sent the price of tradable permits spiraling. The experience of California suggests that careful heed must be paid to the risk that the price of tradable permits can rise higher than expected at the time of designing the system.

For these reasons, the U.S. is very skeptical as to whether the Kyoto Protocol is fundamentally practical, while at the same time it advocates sincere commitment to global warming abatement. These arguments of the U.S. can be simply dismissed as self-righteous. They are, however, underlined by the firm belief that the sheer magnitude of the political and economic impacts of the Kyoto Protocol is reason for cool and pragmatic consideration. The U.S. strongly feels that the Kyoto Protocol is a trap laid by the EU in the hope of weakening the international competitiveness of the U.S. industry, and that the protocol unfairly benefits its “strategic competitors,” notably China and Russia.

If we replace the “U.S.” with “Japan” in these arguments, it is clear that Japan cannot remain idle in the present mood of an intensifying “power game” among countries in dealing with the global warming issues. Also, as pointed out (4 above) by the U.S. with its rich experience of emissions trading, in the present situation where an emissions trading system has not been firmly established, it would be very risky to promote ratification of the Kyoto Protocol without verifying its validity.

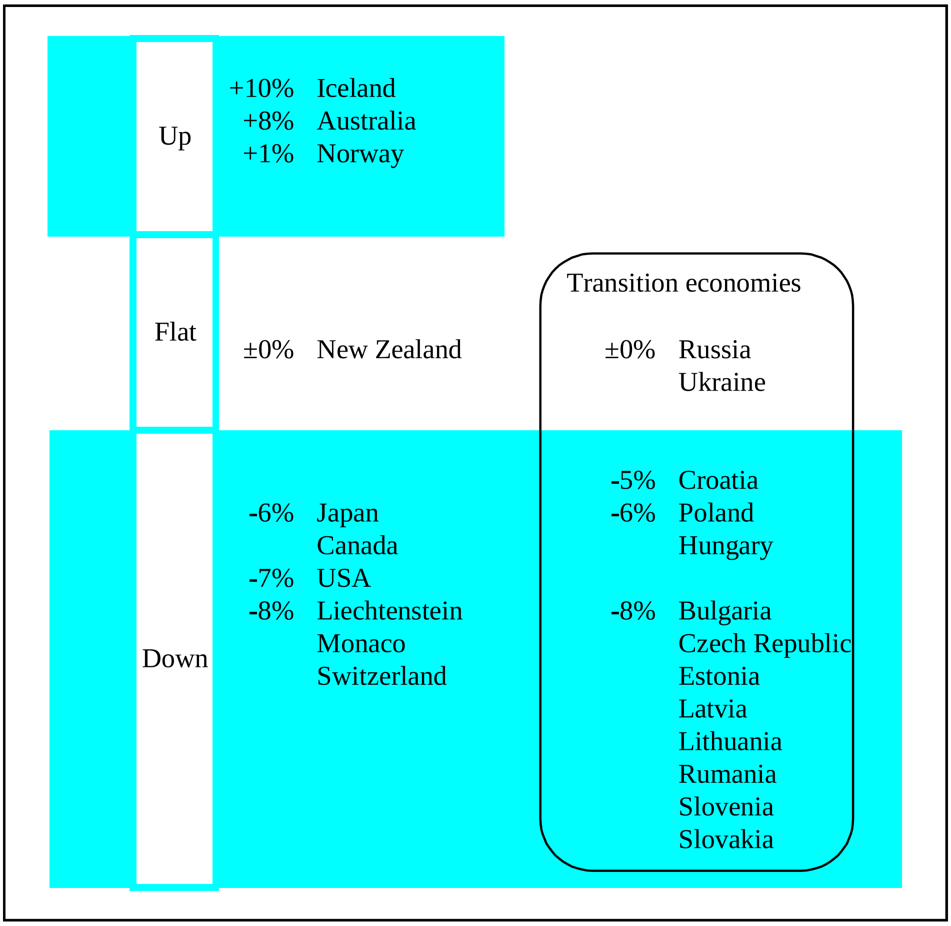
With regard to CO_2 emissions trading, it has not yet been confirmed whether or not the international market can function well. Moreover, depending on responses to banking (carryover) on the supply side—chiefly the former Soviet Union and East Europe—the price of tradable permits could spiral. Banking means that any country whose GHG emissions in a commitment period remain below a given Kyoto target is allowed to carry the gap over to the next commitment period as a surplus to its assigned emissions. In reflection of their sluggish economies, the former Soviet Union and East European countries are permitted to have their emissions remain considerably below the Kyoto targets (so-called hot air) without making any efforts to reduce them, and thus have such options as banking the surpluses or selling them on the international market. If the supply side prefers banking in anticipation of a higher price of tradable permits in the second commitment period, the price of tradable permits in the first commitment period (2008-2012) will not be very cheap. Thus, if buyers stick to meeting the Kyoto targets, such behavior can send the price of tradable permits soaring.

4-2 GHG reductions assigned

The Kyoto Protocol provides that the parties specified in Annex B[4] are required to set GHG reduction targets from their 1990 records and to meet the targets in terms of annual average emissions during the period from 2008 to 2012. The targets shown in Fig. 4-1, if met by individual parties, amount to a 5.2% cut in GHG emissions by Annex B parties from their 1990 levels. In regard to commitments at home and abroad, the topic of CO_2 attracts the greatest attention, because CO_2 is the by far the largest contributor to global warming among the target GHGs, and because efforts to reduce it can have very serious impacts on the economic activities of each country.

[4] Annex B parties: defined as virtually identical to Annex I parties under the Kyoto Protocol, the Framework Convention on Climate Change.

Fig. 4-1 GHG Reductions Targets Assigned



Source: IEEJ data

4-3 Kyoto Mechanism

The Kyoto Mechanism provides trading methods designed to enable transaction of GHG reductions in the form of credits, the purpose being to minimize the cost of GHG reduction incurred by trading entities and ultimately worldwide. In specific terms, it includes (1) emissions trading, (2) joint implementation (JI) and (3) clean development mechanism (CDM). In Japan and other countries having advanced levels of energy conservation, the marginal GHG abatement cost is very high. On the other hand, countries in which economic levels remain relatively low or energy efficiency improvements are still under way have many low-cost options in reducing GHG emissions. Focusing on the differences in the marginal cost, the Kyoto Mechanism enables such countries and business operators on both sides to enjoy economic merits of their own by trading permits through a "market." To make this market trading real globally requires an organization responsible for certification of credits, management of trading, etc. In the meantime, the COP7 held in

November 2001 in Marrakech agreed on the following matters related to the Kyoto Mechanism.

(1) The Kyoto Mechanism should be supplementary to domestic actions, but not constrained in quantitative terms.
(2) If registered by their national governments, business operators are also qualified to participate in the trading.
(3) A variety of credits are mutually convertible and freely tradable among the industrialized parties.
(4) JI and CDM are valid for the projects from 2000 onward.
(5) Rulemaking should ensure preferential introduction of small-scale CDM.
(6) Financial additions into CDM projects will, in effect, not be questioned.

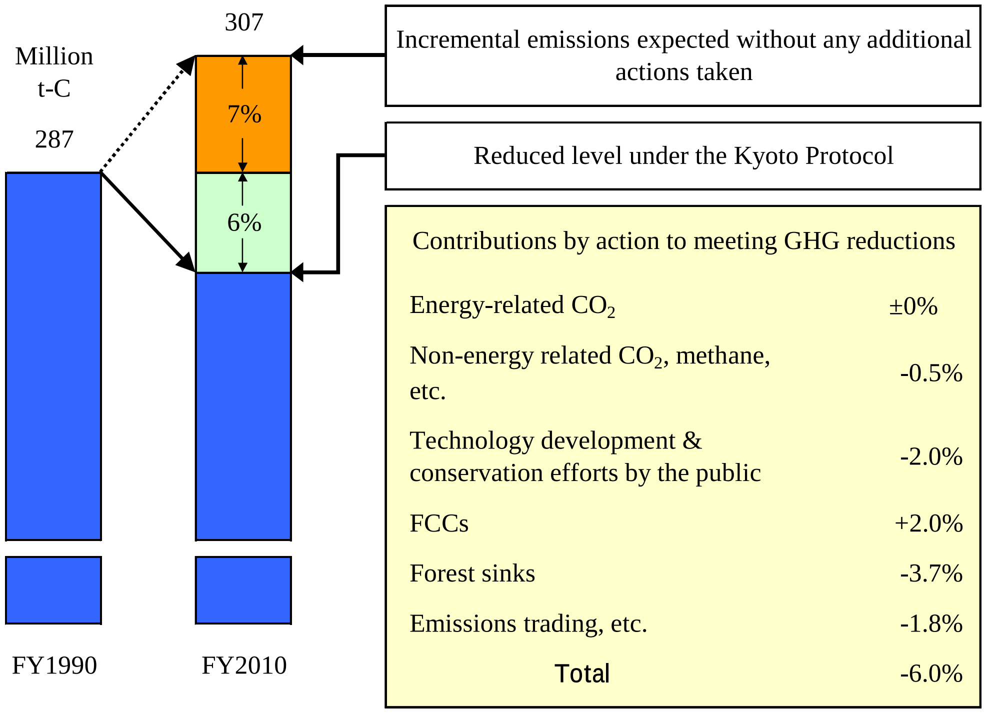
4-4 Guidelines to CO_2 reductions issued by the Headquarters for the Promotion of Global Warming Abatement, and related tasks

A Cabinet meeting on December 12, 1997 decided to set up within the cabinet a Headquarters for the Promotion of Global Warming Abatement. The Headquarters is expected to facilitate specific and effective measures aimed at mitigating global warming generally in an effort to bring about steady implementation of the Kyoto Protocol adopted at the Third Conference of Parties to the United Nations Framework Convention on Climate Change.

On June 19, 1998, the Headquarters decided on the “General Rules for the Promotion of Global Warming Abatement” (former general rules). Later, on March 13, 2002, the Headquarters disclosed the gist of revised general rules drafted in reflection of the document, adopted at COP7, to provide details of how the Kyoto Protocol should operate. Based on the latest report of the Advisory Committee for Resources and Energy, the draft sets forth the GHG reduction scenario shown in Fig. 4-2 in relation to cutting CO_2 emissions caused by energy use. A key point of this scenario is its assumption that energy-origin CO_2 emissions in FY2010 could be offset at the same level as in FY1990. In specific terms, this assumes energy-origin CO_2 emissions in FY2010 to be 307 million t-C, larger by 20 million t-C than in FY1990. However, the scenario states that the incremental 20 million t-C could be offset by energy conservation efforts (6 million t-C), introduction of new energy (9 million t-C) and fuel switching (5 million t-C), among others. In other words, this scenario intends to cut CO_2 emissions through domestic actions alone without taking the Kyoto Mechanism into account as a means of trimming energy-origin CO_2 emissions. Under this scenario, GHG reductions through emissions trading and the like remain at 1.8% out of a 6%

cut that Japan is obliged to meet under the Kyoto Protocol. On the other hand, COP7 agreed that "the Kyoto Protocol should be supplementary to domestic actions, but will not be constrained in quantitative terms."

Fig. 4-2 GHG Reduction Scenarios



Source: Prepared by IEEJ on the basis of "General Rules for the Promotion of Global Warming Abatement" and the draft of its revision.

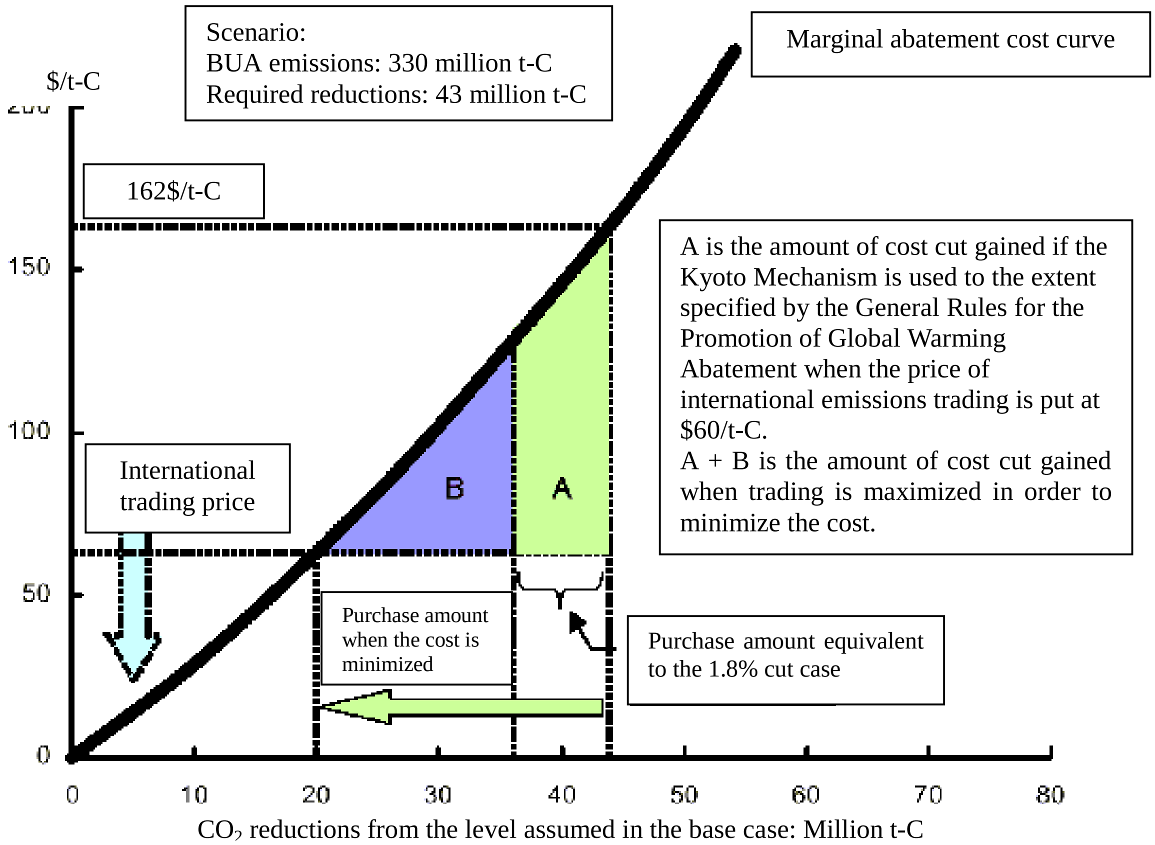
4-5 Required energy-origin CO_2 reductions

The base case in the latest report of the Advisory Committee for Resources and Energy states that if no additional conservation measures to existing ones are taken, CO_2 emissions could reach 307 million t-C in 2010, up 6.9% over the 287 million t-C recorded in 1990. This means an excess of 20 million t-C. It should be noted, however, that very ambitious energy conservation is already interwoven into this case, and that the mandatory CO_2 reductions put at 20 million t-C in the "General Rules for the Promotion of Global Warming Abatement" are rather conservative. Indeed, according to the U.S. DOE (the base case of "International Energy Outlook 2001" by the EIA), the gap (increment) between likely emissions in 2010 and 1990 records will amount to 61 million t-C, three times the projection made by the ACRE.

4-6 Calculations of the Kyoto Mechanism in use

We consider the potentials of the Kyoto Mechanism in use by Japan on the basis of a study made by the Massachusetts Institute of Technology (Fig. 4-3). The business-as-usual (BAU) case of the MIT study puts CO_2 emissions at 330 million t-C. Given the 287 million t-C recorded in 1990, Japan is required to cut 43 million t-C. Fig. 4-3 shows the relation between the required CO_2 reductions and the marginal abatement costs. If the entire 43 million t-C is cut through domestic actions alone, the cost will ultimately rise to US$162/t-C. Thus, if the international price of tradable permits is US$60/t-C, it would be more advantageous for Japan to implement domestic actions until the marginal cost reaches US$60/t-C and then to buy the permits for US$60/t-C to the extent necessary for offsetting

Fig. 4-3 Validity of Kyoto Mechanism in Japan



Source: Prepared by IEEJ in reference to the data contained in MIT report 41, 1988 by A. D. Ellermann, H. D. Jacoby and A. Decaux.

the remaining required reductions. In Fig. 4-3, the domain of A + B represents the resultant cost reduction, which amounts to about US$1.2 billion, which is equivalent to 37% of the cost incurred when domestic actions alone are taken (Table 4-1, Case III). What will be the result in case of constrained emissions trading (Table 4-1, Case II)? If Japan buys permits up to 1.8% of the 287 million t-C recorded in 1990 (= 5.17 million t-C), as assumed in the "General Rules for the Promotion of Global Warming Abatement," the potentials of cost cut will be limited to within the domain of A alone, or about US$500 million (15%). Thus, constraining emissions trading or other instruments under the Kyoto Mechanism can bring about extreme disadvantages in cost terms.

Table 4-1 Cost Cut Effects of Emissions Trading

	Total cost ($100 million)	Difference in total cost ($100 million)	Cost cut (%)	Average cost (US$/t-C)
I. Domestic actions alone	31.5	-	-	73
II. Domestic actions + restrained emissions trading: 1.8%	**26.9**	4.7	15	62
III. Domestic actions + emissions trading	19.8	11.7	37	46

Note: Roughly calculated from Fig. 4-3.

While the MIT study puts the marginal abatement cost incurred with domestic actions alone at US$162/t-C, other research institutes produced different reports. Table 4-2 contains shows the marginal abatement costs for the U.S., Europe and Japan with no emissions trading. According to this, the cost for Japan amounts to US$23 – 222. Compared with Japan's, Europe's cost is a little lower, and the U.S. cost is much lower. This suggests that the marginal abatement cost could be lowered to US$6 – 36/t-$CO_2$ with emissions trading in practice among Annex B parties to the Kyoto Protocol, and even to US$4 – 24/t-$CO_2$ if it were in practice worldwide after getting the developing parties involved.

Table 4-3 shows the impacts that such emissions trading would produce on GDP. In the case of Japan, which has a high marginal abatement cost, GDP drops by 0.25 – 1.2% with no emissions trading (domestic actions alone). The table also shows that GDP can drop by 0.1 – 0.2% with emissions trading in practice among Annex I parties to the FCCC, and by 0 – 0.2% if in practice worldwide. Thus, emissions trading (Kyoto Mechanism) has the potential for a massive impact on the macro economy.

Table 4-2 Marginal Abatement Cost (Effects of Emissions Trading)

(Unit: US$/t-$CO_2$)

Model	No trading US	No trading Europe	No trading Japan	Annex B Trading	Global Trading
SGM	48			22	8
MERGE	81			34	24
G-Cubed	19	49	74	11	4
POLES	24	38 – 41	71	33	10
GTEM	111	228	222	36	
WorldScan	11	23	26	6	
GREEN	44	58	23	20	7
AIM	49	63	75	19	13
Average	48	77	82	24	8

Note: Differences between models can be explained by: (a) variations in business-as-usual projections of CO_2 emissions, which determine the magnitude of the effort; (b) different assumptions on the availability and cost of less carbon-intensive technology; (c) the extent to which end-use energy and corresponding prices and taxes are treated in detail, as they affect the level of the additional tax to reduce emissions.

Sources: SGM: Sands et al (1998), MERGE: Manne and Richels (1998), G-Cubed: McKibbin et al. (1998), POLES: Capros (1998), GTEM: Tulpulé et al. (1998), WorldScan: Bollen et al. (1998), GREEN: Van den Mensbrugghe (1998.a), AIM: Kainuma et al. (1998).

Source: IEA, "International Emission Trading - From Concept to Realty."

Table 4-3 Impacts of Emissions Trading on Ups/Downs in GDP

Model	Region	No emissions trading	Emissions trading in practice Annex I parties	Emissions trading in practice Worldwide
SGM	USA	-0.4%	-0.28%	-0.12%
MERGE	USA	-1%	-	-0.25%
G-Cubed	USA	-0.3%	-0.2%	-0.2%
	Japan	-0.8%	-0.2%	-0.2%
	Rest of OECD	-1.4%	-0.5%	-0.2%
GTEM	Annex I parties	-1.2%	-0.3%	-
GREEN	Annex I parties	-0.5%	-0.1%	-
AIM	USA	-0.45%	-0.3%	-0.2%
	Japan	-0.25%	-0.15%	0%
	EU	-0.3%	-0.17%	-0.07%

Note: For the names of the models, see the note in Table 4-2.

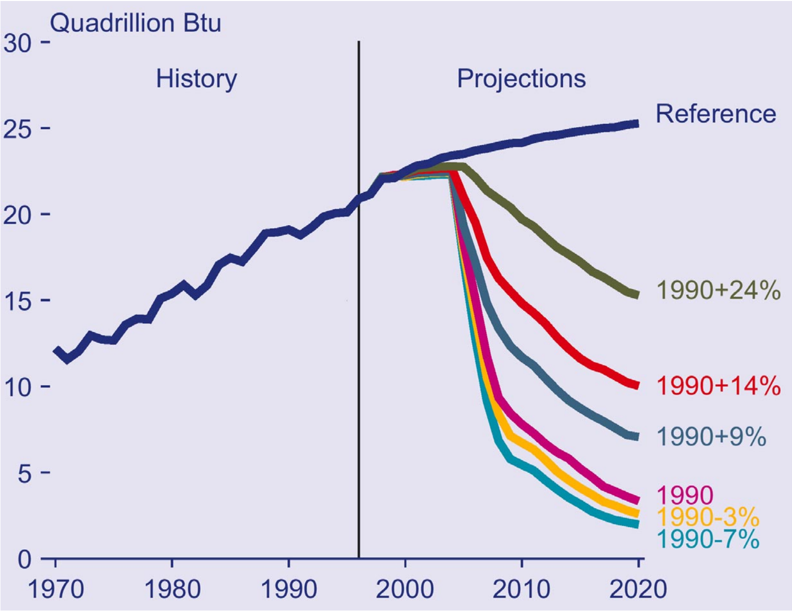
Source: IEA, "International Emission Trading - From Concept to Realty."

5. Impacts of Global Warming Abatement on Coal Supply and Demand

5-1 Calculations by the U.S. EIA

Concerning the impacts that the Kyoto Protocol could produce within the U.S., in 1998 the EIA of the U.S. Department of Energy conducted a study entitled "Impacts of the Kyoto Protocol on the U.S. Energy Markets and Economic Activity." This study report states that, without the Kyoto Protocol (base case), coal demand would amount to 24.14 X 10^{15} Btu (870 million tce) in 2010. Thus, if CO_2 emissions are cut by 7% from 1990 records through domestic actions, coal consumption will shrink drastically to 5.44 X 10^{15} Btu (196 million tce) (Fig. 5-1). The EIA study prepared five other cases, each assuming CO_2 emissions up 24%, up 14%, up 9%, flat 0%, and down 3% compared with 1990 records. In these cases, coal demand in 2010 is estimated at 19.70 X 10^{15} Btu, 14.81 X 10^{15} Btu, 11.68 X 10^{15} Btu, 7.80 X 10^{15} Btu, and 6.72 X 10^{15} Btu, respectively. In terms of coal equivalent, they turn out to be 710 million tce, 534 million tce, 421 million tce, 281 million tce, and 242 million tce, respectively.

Fig. 5-1 U.S. Coal Demand Outlook



Source: US DOE, IEA

Coal demand of 196 million tce is lower by as much as 77% than in the base case, which could mean the demise of the U.S. coal industry. If the record-low coal output for the last 50 years stays at 376 million tce in the U.S., this could deal a fatal blow to the coal industry.

5-2 Calculations by CRIEPI

The Central Research Institute of Electric Power Industry (CRIEPI) reported that if Japan achieved the Kyoto target by reducing CO_2 through domestic actions such as an environmental tax, the coal/coke demand in 2010 could fall by as much as 35.6% from the BAU case. As shown in Table 5-1, the CRIEPI puts coal demand for 2010 at 119 million kl crude oil equivalent (157 million tce) in its BAU case. A 35.6% drop means that coal demand would plunge sharply to 101 million tce, equivalent to the level of about 20 years ago.

Table 5-1 Energy Supply Outlook by CRIEPI

(100 million crude oil equivalent)

	1977: actual	2000	2010	2025
Total	6.04	5.99	6.35	6.67
Coal	1.02	1.03	1.19	1.26
Oil	3.24	3.18	3.08	2.99
Natural gas	0.70	0.73	0.79	0.88
Hydro	0.23	0.21	0.21	0.21
Nuclear	0.78	0.77	0.98	1.19
Geothermal	0.01	0.01	0.01	0.01
New energies/others	0.07	0.07	0.08	0.13
Share (%)				
Coal	16.9	17.1	18.8	18.9
Oil	53.6	53.0	48.5	44.8
Natural gas	11.6	12.2	12.5	13.2
Hydro	3.8	3.4	3.2	3.1
Nuclear	12.9	12.8	15.5	17.9
Geothermal	0.2	0.2	0.2	0.2
New energies/others	1.1	1.2	1.3	1.9

Source: Pprepared by IEEJ on the basis of CRIEPI, “The Japanese Economy with Environmental Taxation Introduced: Impacts on Energy Demand.”

In its calculations, the CRIEPI assumed the amount of the environmental tax to be ¥33,000/t-C in FY2010, which would send the prices of coal, crude oil and LNG rising by about six times, 2.2 times and 1.9 times, respectively, compared with those in the pre-taxation period. Coal price shows the highest rate of increase because coal is cheap in the first place and the tax is imposed on carbon contents.

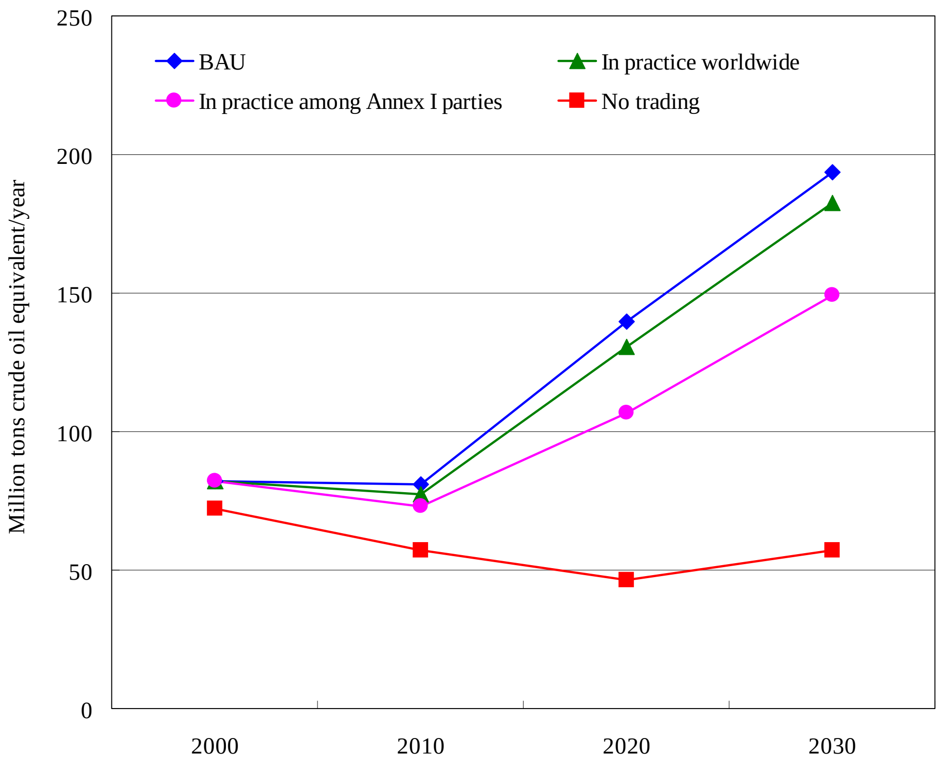
5-3 Calculations by EPDC

Electric Power Development Co. (EPDC) calculated the coal demand in Japan and the world assuming that the Kyoto Mechanism was in use. The calculation result is outlined below.

5-3-1 Kyoto Mechanism in use and Japan's coal consumption

Assuming various cases of the Kyoto Mechanism in use, EPDC calculated the resultant changes in Japan's coal consumption. These are plotted in Fig. 5-2. When CO_2 reductions were to be attempted through domestic actions alone without application of the Kyoto Mechanism, energy conservation and fuel switching from coal to alternative fuels would be implemented. As a result, coal consumption would drop considerably from the BUA case. On the other hand, if the Kyoto Mechanism is put to effective use worldwide, the Mechanism will help promote successful commitments and coal consumption will come close to reaching the BUA case. This trend is common to the U.S. and West Europe.

Fig. 5-2 Kyoto Mechanism and Japan's Coal Consumption

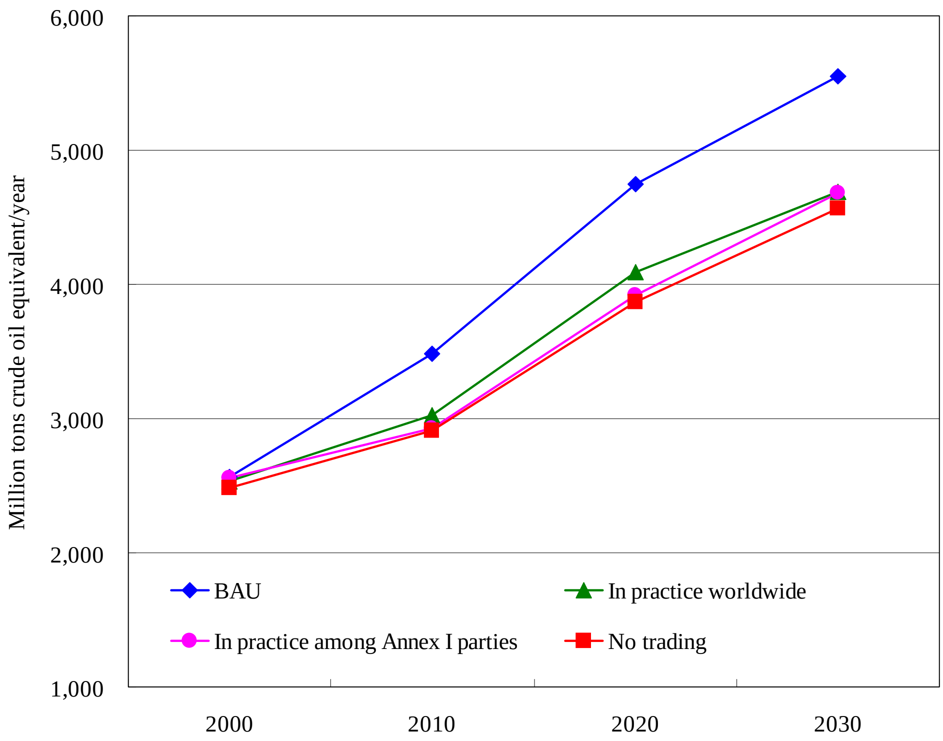


Source: Yuzuru Nonaka, JAPAC International Exchange Forum, 1999

5-3-2 Kyoto Mechanism in use and the world's coal consumption

Similarly, EPDC calculated the world's coal consumption, the results of which are shown in Fig. 5-3. The world's coal consumption remains unchanged and higher, though falling below the BUA case. Unlike the Japanese case, few conspicuous differences are noted in coal consumption, either, as a result of the different scopes of the Kyoto Mechanism in practice. This suggests that the impacts of the Kyoto Mechanism on coal consumption vary according to country. The points mentioned above can be summarized as follows.

Fig. 5-3 Kyoto Mechanism and World's Coal Consumption



Source: Yuzuru Nonaka, JAPAC International Exchange Forum, 1999

(1) Without the Kyoto Mechanism in use, coal consumption in Annex I parties is likely to remain sluggish. However, the world's coal consumption will increase because coal consumption in non-Annex I parties continues to grow normally (business as usual). Falling coal consumption in Japan, among others, affects coal flow in the world.

(2) If the Kyoto Mechanism is in practice only among Annex I parties, the trend in world coal consumption remains virtually unchanged from the no trading case. However, the rate of falling coal consumption in Japan and elsewhere can be much limited.

(3) If the Kyoto Mechanism is in use worldwide, coal consumption in the Annex I parties comes close to the BUA case. However, because coal consumption declines in

non-Annex I parties, which supply credits to Annex I parties, the world's coal consumption will not show significant differences from the remaining cases.

Meanwhile, Table 5-2 shows the marginal abatement costs in the cases calculated by EPDC.

Table 5-2 CO2 Abatement Marginal Cost

Scope of Kyoto Mechanism in practice	Not in practice (by Japan)	Annex I parties	Worldwide
Marginal abatement cost ($/t-C)	350	70	25

Source: Yuzuru Nonaka, JAPAC International Exchange Forum, 1999

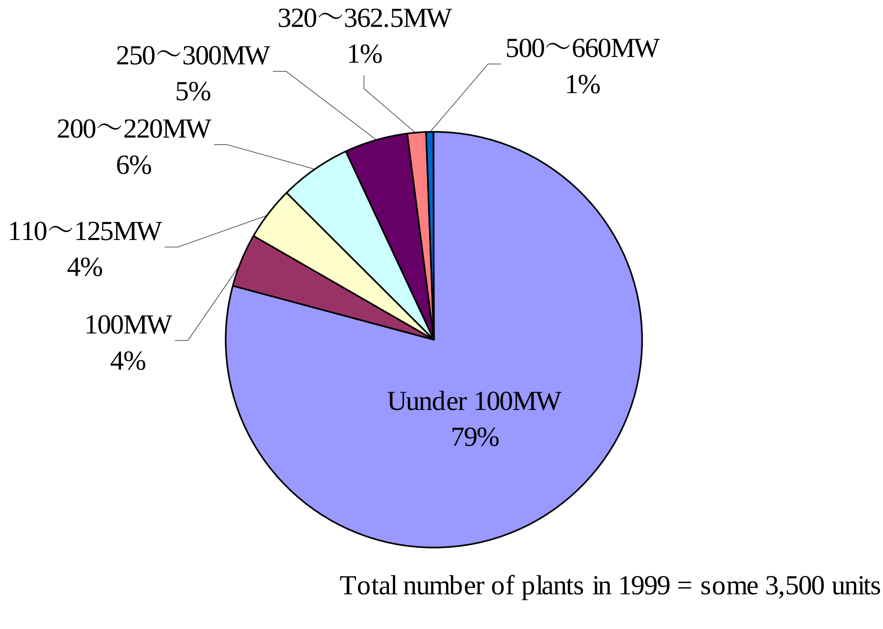
6. Potential CO_2 Reductions at Chinese Coal-fired Plants: Seeds of Kyoto Mechanism

China is the world's largest coal-consuming country. The EIA states in its "International Energy Outlook 2001" that China's coal demand, 975 million tons in 1999, will reach 1,642 million tons by 2010. CO_2 emissions resulting from China's coal burning are formidable in size. If its coal consumption could be curbed by 10% by improving the thermal efficiency of coal use, China could conserve over 100 million tons of coal. Providing help to China in improving the efficiency of its coal use could well be a trump card in promoting the world's CO_2 reductions. Japan has coal-fired power plants of supercritical pressure and super-supercritical pressure type, the construction and operation of which have already been demonstrated. By virtue of its clean coal technologies, Japan may have ample occasions to offer technology cooperation to China and many other developing countries in this field.

6-1 Status of China's coal-fired plants and potential thermal efficiency gains

According to Zhao Zongrang, China's installed capacity surpassed 300 GW as of late April 2001, compared with 298.80 GW at the end of 1999 when annual generated output totalled 1,233.1 TWh. Above all, the share of fossil-fired power stood at a high 82%, of which coal-fired power accounted for as much as 95%, or 958.6 TWh. By size, the majority of coal-fired power plants all have a capacity of under 100 MW. That is, 2,800 plants, or 79% of the total, reportedly fall in this category (Fig. 6-1, Table 6-1). Those capable of producing over 500 MW account for a mere 1% (23 plants) of the total. Of these, 16 plants have a capacity of 600 MW or 660 MW. As shown in Table 6-1, the power plants with a limited capacity are found to be the most fuel-intensive, reflecting their lower vapor pressure and poorer generating efficiency. Vapor parameters of the Chinese fossil-fired plants show that 97% of the total operate at subcritical pressure or under. As of July 2000, fossil-fired plants of supercritical pressure amounted to only 5.20 GW in total. The coal intensity of small coal-fired plants in China is 550 g/kWh, compared with the 399 g/kWh that is the average of the country's coal-fired plants. The National Electric Power Corporation of China intends to halt or scrap small coal-fired plants gradually in the future. According to its plan, small coal-fired plants of 7.74 GW will be scrapped between 1998 and 2001, and an additional 14.00 GW by the end of 2004. From now on, the mainstream of newly built coal-fired plants will be supercritical-pressure plants, which are expected to achieve generating efficiency as high as 45%, while coal intensity will remain at 310 – 320 g/kWh. Replacing 14 GW of small coal-fired plants with supercritical-pressure plants will allow coal conservation of 15 million tons.

Fig. 6-1 Chinese Fossil-fired Plant Mix by Capacity



Source: Zhao Zongrang, "Develop supercritical coal- fired units to optimize China's thermal power structure", 8th APEC Coal Flow Seminar (2002)

Although the calorific value of coal is not specified in the report of Zhao Zongrang, it is reportedly 5,970 – 6,160 kcal/kg (6,065 kcal/kg on average) when calculated back from coal intensity and generating efficiency. Thus, calculating from this calorific value and coal intensity (399 g/kWh), we find that the average generating efficiency among the Chinese coal-fired plants is 35-36%. Similarly, the average generating efficiency among small coal-fired plants (coal intensity = 550 g/kWh) is found to be 25-26%. As we verified from actual data contained in the Chinese Electricity Yearbook (2000 edition) and other sources, coal-fired generated output in 1999 totaled 958.6 TWh, which involved coal consumption of 481.87 million tons. With the calorific value of coal employed in the Chinese coal statistics, namely 5,000 kcal/kg, converted into 6,065 kcal/kg, the stated coal consumption turned out to be 397.25 million tons. Accordingly, coal intensity stands at 414 g/kWh and generating efficiency at 34%. Compared with the figures reported by Zhao Zongrang, coal intensity is higher by about 15 g/kWh and generating efficiency lower by 1% or so—which do, however, come within allowable error. If China's coal intensity drops from an average 399 g/kWh nationwide to 315 g/kWh recorded by supercritical pressure power generation, China could achieve savings in its coal consumption of as much as 80.50 million tons (= 958.6 TWh (1999 generated output) X (399 – 315)/100). In terms of 5,000 kcal/kg, this represents coal conservation of 97.60 million tons, equivalent to 20% of coal burned at coal-fired plants during 1999.

Table 6-1 Chinese Fossil-fired Plant Mix by Capacity

Installed capacity	Number of plants (units)	Total capacity (MW)	Share (%)	Vapor pressure/temperature
Uunder 100MW	2,800	70,000	31.0	
100MW	144	14,400	6.4	8.8Mpa/535℃
110～125MW	152	18,915	8.5	8.8Mpa/535℃
200～220MW	195	39,140	17.5	12.2Mpa/535/535℃
250～300MW	170	51,136	22.3	16.6Mpa/538/538℃
320～362.5MW	50	17,252	7.7	16.6Mpa/538/538℃
500～660MW	23	13,300	5.9	16.6Mpa/538/538℃
Total	3,500	223,434	100.0	

Source: Zhao Zongrang, "Develop supercritical coal- fired units to optimize China's thermal power structure", 8th APEC Coal Flow Seminar (2002)

China intends to emphasize the introduction of efficient power generation in the future, which may involve cooperation with foreign capital as a crucially important element. Because this is an area in which where Japan is strong, the Kyoto Mechanism can be implemented through cooperation in China. The potentials here are very big.

6-2 Thermal efficiency of a Chinese coal-fired plant improved by KEP

In 1998, Kyushu Electric Power Inc. made a proposal to Shandong Electric Power (SEC) of China for improvement of the thermal efficiency of the No. 7 unit of its Huang Tai coal-fired plant. In 2000, SEC adopted this proposal in its entirety and conducted the necessary works for improvement. As a result, the thermal efficiency was improved by 4.40% and fuel consumption reduced by 88,000 tons/year (Table 6-2). Moreover, SEC succeeded in reducing CO_2 emissions by 212,000 t-CO_2 a year. Details of the improvements and measures taken are summarized in Table 6-3. Location and other facts concerning the No. 7 unit are shown in Fig. 6-2.

Table 6-2 Results of Huang Tai Coal-fired Plant No. 7 Unit Thermal Efficiency Improvement Project

	Before improvement (1998/7)	After improvement (2000/10)	Effect of improvement
Thermal efficiency	33.17 %	37.57 %	+4.40%
Fuel consumption (10,000 t/y)	75.2	66.4	-8.8
Fuel cost (¥100 million/y)	29.3	25.9	-3.4
CO2 emissions (10,000 t-CO_2/y)	180.9	159.7	-21.2

Note: The fuel costs are based on the coal price paid by Shandong Electric Power.
Source: Etsuo Ohyama, JAPAC Workshop (December 10, 2001)

Because China has a large number of small coal-fired plants, efficiency gains such as those achieved at the No. 7 unit of SEC, if applied to many other plants, can produce conspicuous effects nationwide. KEP’s achievement, an example of a successful technology transfer project from Japan, should encourage further efforts by Japan to promote technology transfers for the sake of global warming abatement. Technology transfers in this field can also provide seeds for implementation of the Kyoto Mechanism.

Table 6-3 Causes of Poor Efficiency and Measures Taken

Item		How improved
Boiler-related	Falling amounts of heat absorption on heating surface of boiler	(1) Washed heating surface. (2) Reset vapor blasting pressure at adequate level, and resumed operation of the existing soot blower. (3) Installed additional soot blowers.
	Falling amounts of heat exchange by the air preheater	(1) Exchanged and washed heat-transfer parts of the air preheater. (2) Replaced leaking vapor tubes of the vapor-type air preheater.
Turbine-related	Increasing losses due to deterioration of aging high-pressure turbine	(1) Removed scales and replaced fins.
	Increasing losses due to deterioration of aging low-pressure turbine, etc.	(2) Newly manufactured moving blades with fins, the originally installed units of which were not equipped with edge. (3) Newly manufactured the internal chamber and diaphragm.
	Deteriorating thermal efficiency due to generation of reheater sprays	(1) Automated operation of the chilling unit of burner nozzles, and tried to reduce amount of sprayed water of the reheater.
In-plant electricity consumption increased due to mounting losses of the air flue pressure		(1) Removed ashes and others from the air flue. As a result, in-plant power use dropped by about 10%.

Source: Etsuo Ohyama, JAPAC Workshop (December 10, 2001)

Fig. 6-2 Facts of Huang Tai Coal-fired Plant No. 7 Unit

Location: suburbs of Jinan City, Shandong Province

Power: 300 MW

Annual generated output: 1.9 TWh (utilization factor: about 70%)

Fuel in use: indigenous coals originating in China

Commissioned in: November 1987

Vendors: boilers manufactured by Mitsubishi Heavy Industries; turbines by Dongtang Electric Corporation

Source: Etsuo Ohyama, JAPAC Workshop (December 10, 2001)

Conclusions

Through our study/analysis of the impacts that global warming abatement could produce on coal supply and demand, we have ascertained the following:

(1) Japan's CO_2 emissions in the future can considerably exceed the levels projected by the Advisory Committee for Resources and Energy.

(2) If CO_2 emissions are reduced through such domestic actions as environment/carbon taxes alone, the marginal abatement cost will be so high that they could send Japan's coal demand plunging and devastate the coal industry.

(3) If CO_2 emissions are cut by virtue of a global system, represented by the Kyoto Mechanism, the marginal abatement cost can be significantly lowered. However, if introduction of the Kyoto Mechanism is in some way limited, its effects will also be constrained. Furthermore, as the Kyoto Mechanism has not as yet been firmly established on a global basis, various risks are still present.

(4) Big potentials exist for achieving CO_2 cuts by increasing the thermal efficiency of power plants, particularly coal-fired plants, in China, the world's largest coal-consuming country. On the strength of its rich expertise and experience in construction/operation of efficient coal-fired power plants, Japan has opportunities to cooperate in many ways in this field, while such cooperation also contains the seeds for successful implementation of the Kyoto Mechanism.

Contact: ieej-info@tky.ieej.or.jp

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