CO_2 Reduction Potentials in Japan

UNFCCC COP5

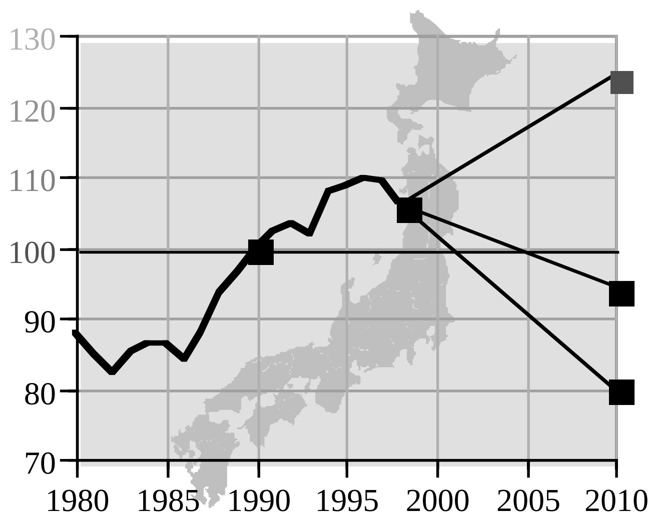
25 October - 5 November 1999, Bonn

Citizens Alliance for Saving the Atmosphere and the Earth

CASA Climate Change Strategy Team
1-3-17-711 Tanimachi, Chuo-ku, Osaka 540-0012, JAPAN
Phone: +81-6-6941-3745 Fax: +81-6-6941-5699
E-mail: casa@netplus.ne.jp

Summary

- CO_2 reduction potentials in Japan were investigated in this report.
- In BAU case (Scenario 0), the CO_2 emission was estimated to increase by 25% from 1990 level.
- In Technology case (Scenario 1), the CO_2 emission was estimated to decrease by 6.5%.



Part 1

1. The Objective of this Report

The objective of this report is to update CASA's "Proposals on CO_2 Emission Reduction Strategy - Phase I Report" (http://www.netplus.ne.jp/casa/co2/index-phase1-e.html) announced in 1997, making use of most recent statistical data, etc., and to reevaluate possibilities for greenhouse gas emission reductions in Japan.

2. Methodology

2.1 Scope of Greenhouse Gases to be Evaluated

This study evaluates Japan's carbon dioxide emissions. In Japan, carbon dioxide accounts for most (90%) of the global warming effect of the 6 greenhouse gases covered by the Kyoto Protocol (Table 1).

The carbon dioxide emission sources covered by this report are fuel combustion, industrial processes and waste management. Emissions due to combustion of biomass (black liquid, waste paper, etc.) were also included in the CASA Phase I Report announced in 1997, but were excluded from the present report, as in the Japanese government's "Second National Communication Report" (1997). Furthermore, the only emissions from industrial processes that have been included are emissions due to decomposition of limestone (primarily from the manufacture of iron, steel and cement); emissions due to ammonia manufacture, which are accounted for in Japan's Second National Communication Report, have not been included.

Table 1 : GHG emissions from Japan (unit: Tg-CO_2)

Gas type	1990	1993	1995	1996	1997
CO_2	1,124.5	1,143.8	1,219.4	1,235.6	1,230.8
CH_4	32.4	31.6	31.0	30.4	29.2
N_2O	18.1	17.6	19.3	20.1	20.4
HFC	17.7	20.9	29.9	30.1	34.1
PFC	5.7	8.5	15.1	17.1	17.0
SF_6	38.2	45.4	52.6	51.0	49.7
Total	1,236.6	1,267.8	1,367.4	1,384.3	1,381.2
CO_2/Total	90.9%	90.2%	89.2%	89.3%	89.1%

2.2 Division of Sectors

In accordance with the division of sectors used in government energy statistics, the energy-related emission sources have been divided into 5 sectors: the industrial, transportation, residential, and commercial sectors (final demand sectors) and the energy conversion sector (Figure 1). Furthermore, a waste management sector, which accounts for emissions due to waste incineration, has been defined. Emissions due to industrial processes have been handled as emissions from the industrial sector.

The following three points were considered regarding interactions between sectors:

a. The energy conversion sector generates electric power according to the demand for power in the final demand sectors.

b. CO_2 emissions due to waste power generation at waste incineration facilities are accounted for in the waste management sector. These estimates are also reflected in the calculations of power generation in the energy conversion sector. Thus, waste power generation is considered to generate no CO_2 emissions in the energy conversion sector.

c. The amount of waste plastic used as a CO_2 emissions reduction measure in the industrial sector (the iron and steel sector) was set lower than the amount of waste plastic generated in the waste management sector. (Use of waste plastic instead of coke as a reducing agent in the iron/steel furnace reduces total CO_2 emissions, as waste plastic would be incinerated whether or not reused in this way.)

Other interactions between sectors (e.g., variations in the amount of wastes in the waste management sector accompanying variations in production in the industrial sector) were not considered.

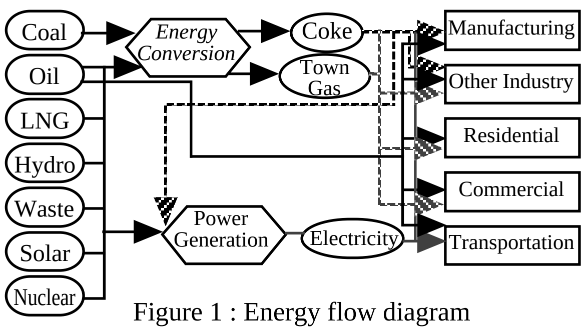


Figure 1 : Energy flow diagram

2.3 Final Demand Sectors

2.3.1 Analysis of the energy demand structure of each sector

The energy demand structure of each of the final demand sectors was analyzed, and energy demand was broken down into the respective factors in Equation 1:

Energy Demand = $\sum$*Activity Level * Energy Input Per Unit Output …1)*

2.3.2 Preparation of Scenarios

Scenarios 0 through 4 were defined as shown in Table 2

2.3.3 Evaluation of CO_2 Reduction Technologies

CO_2 reduction technologies which could be introduced in each sector were identified, and the extent of their introduction from 2000 through 2010 and their CO_2 reduction effect (reduction in energy consumption) in 2010 were evaluated.

2.4 Waste Management Sector

The amount of waste (waste plastic and waste oil) generated in 2010 was estimated, and used as the Activity Level for Scenarios 0 and 1. A waste reduction factor was applied to calculations of the amount of waste generated in Scenarios 2 through 4.

Waste power generation was assumed to be the same as government estimates in Scenario 0 but higher in Scenarios 1 through 4 due to promotion of new technology.

2.5 Energy Conversion Sector

For energy conversion other than power generation, CO_2 emission levels in Fiscal 1990 were used in each of the scenarios. For the power generation sector, prospects for maximum supply of renewable energy and improvement of thermal efficiency were investigated, and the composition of power sources for each scenario was set as shown in Table 3.

2.6 Calculation of Total Emissions

The carbon dioxide emissions of each sector were added up, and the rate of increase/decrease compared to 1990 levels was calculated.

3. Overview of Results

The results of estimation of carbon dioxide emissions in each of the scenarios are shown in Table 4 and Figure 2.

Table 2 : 5 scenarios for final demand sectors

	Activity Level	Efficiency improvement
Scenario 0	BAU2010	No
Scenario 1	BAU2010	Yes
Scenario 2	same as 1995	Yes
Scenario 3	same as 1990	Yes
Scenario 4	1990 X 80%	Yes

Note: All years mentioned in this report refer to the fiscal year (April - March).

Table 3: 5 scenarios for power generation sector

	Renewable Energy		Nuclear	Thermal Efficiency
	Solar	Wind		
Scenario 0	same as 1995			38%
Scenario 1	Government Target			43%
Scenario 2	1/4 of Max	1/2 of Max	reduced *	43%-46%
Scenario 3	1/2 of Max	1/1 of Max	reduced *	43%-46%
Scenario 4	1/1 of Max	1/1 of Max	reduced *	43%-46%

* No new-construction after 1998. Abandon 30 years old facilities.

Table 4 : Estimated CO_2 emission for each Scenario

Sector	1990	Scenario0	Scenario1	Scenario2
Manufacturing	106.4	110.1	94.8	92.3
Agri, Mining,etc.	13.8	14.4	13.3	13.1
Transportaion	58.7	82.6	65.3	53.0
Residential	17.5	25.3	22.2	18.6
Commercial	16.5	22.8	18.9	15.3
Waste Management	5.0	6.7	6.7	6.2
Power Generation	79.4	111.0	56.0	34.2
Energy Conversion	11.1	11.1	11.1	11.1
Total [million ton-C]	308.4	383.9	288.3	243.7
Changes from 1990	0%	+24.5%	-6.5%	-21.0%

*Emission from power generation is excluded from the final demand sectors

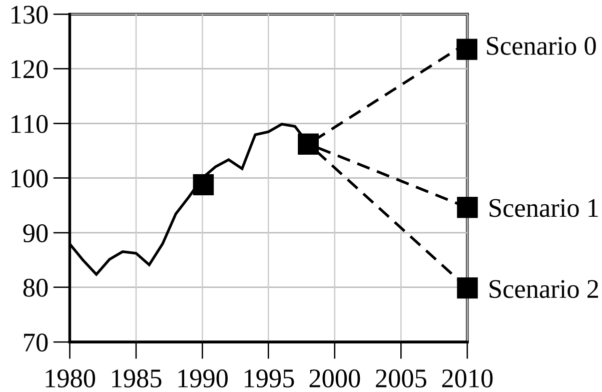


Figure 2 : Trend and prospects of CO2 emission from Japan
unit : index (1990=100)

4. Industrial Sector

4.1 Analysis of Energy Demand Structure and Setting of Activity Level

Σ *output of each sector * CO_2 emissions per unit output*

The industrial sector was sub-divided into 6 sectors: the iron and steel sector, cement sector, paper and pulp sector, other manufacturing sector, agriculture, forestry and fisheries sector, and the mining and construction sector. The output index of each sector was used as the activity level, and the energy consumption per unit output was estimated. CO_2 emissions due to consumption of limestone were treated in the same way as emissions due to energy consumption.

The activity levels for each scenario were set as shown in Table 5.

4.2 Prospects for Reduction of Energy Input per Unit Output

Energy conservation technologies were identified and the maximum energy conservation per 1 ton output was calculated for 3 sectors: the iron and steel sector, cement sector and paper and pulp sector. The effect of recycling was considered in this calculation. Specifically, energy conservation due to improved recycling rate was calculated using equation 2). Conserved energy amounts due to technologies applicable in the respective manufacturing processes were combined to calculate Ep and Es.

$$Eo = (Ep * (1 - r) + Es * r) \ldots 2)$$

Eo: energy input per unit output of the product as a whole

Ep: energy input per unit output of the product produced using primary resources

Es: energy input per unit output of the product produced using recycled resources (normally *Ep*>*Es*)

r: recycling rate

The reduction rates for energy input per unit output calculated for Scenarios 1 through 4 are shown in Table 6. The reduction rate for energy input per unit output in the other manufacturing sector and the mining and construction sector was set at 15%.

4.3 Estimation Results For Each Scenario

The estimation results for each scenario are shown in Table 7. The breakdown of changes in CO_2 emissions between 1990 and Scenario 1 are as shown in Figure 2.

Table 5 : Activity levels for industrial sectors [1000 ton

Scenario	Steel	Cement	Paper	Other*
1990	110,339	86,849	28,086	1.000
Scenario0	94,000	101,000	40,340	1.126
Scenario1	94,000	101,000	40,340	1.126
Scenario2	100,020	97,500	29,660	1.070
Scenario3	90,000	84,000	28,086	1.000
Scenario4	74,000	70,000	24,000	0.800

* index (1990 = 1.0)

Table 6 : Improvement of energy efficiency in industrial sector

Product	Year	Recycle rate	Energy input per unit output*			2010/1990
			recycled	primary	average	
Steel	1990	31.4%	2,660	5,684	4,734	
	2010	35.0%	2,569	5,105	4,218	89%
Cement	1990	18.1%	582	853	804	
	2010	35.0%	582	762	699	87%
Paper	1990	51.8%	3,913	5,363	4,612	
	2010	60.0%	3,502	4,220	3,789	82%
Other	1990					
	2010					85%

* unit : [Mcal/ton]

Table 7: Estimated CO_2 emission from industrial sector

Sector	1990	Scenario0	Scenario1	Scenario2
Steel & Iron	49.6	42.3	37.7	40.1
Cement	22.7	26.4	22.9	22.1
Paper & Pulp	8.5	12.2	10.0	7.4
Other	56.9	64.1	54.5	51.7
Total [million ton-C]	137.7	145.0	125.1	121.3
Changes from 1990	0.0%	+5%	-9.2%	-11.9%

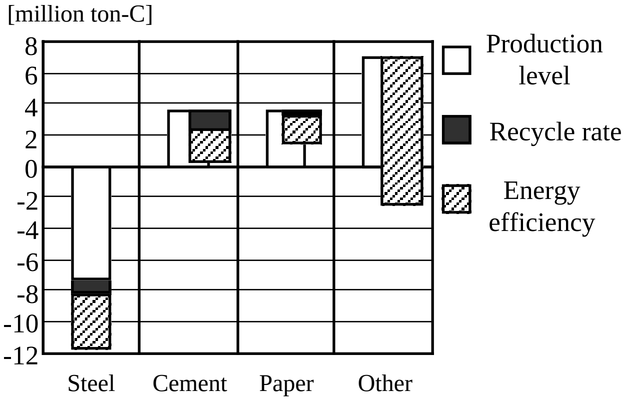


Figure 3 : Factors of CO_2 reduction in manufacturing sector

5. Transportation Sector

5.1 Analysis of Energy Demand Structure and Setting of Activity Level

*Σ distance of transport by each means of transport * fuel input per distance of transport*

The transportation sector was divided in two large categories: automobiles and other means of transportation, and further sub-divided according the means of transport (vehicle type). The distance traveled by each means of transport was used as the activity level, and the fuel efficiency was used as the energy input per unit output.

The activity level in each scenario was set as shown in Table 8.

Table 8 : Activity levels for transportation sector
[billion vehicle-kilometers-traveled]

	Passenger		Freight	
1990	373		256	
Scenario0	542	+45%	355	+39%
Scenario1	542	+45%	355	+39%
Scenario2	453	+21%	267	+4%
Scenario3	373	+0%	256	+0%

Table 9 : Relative fuel efficiency for vehicles*

Vehicle type	New year model		All vehicles in use**
	2000	2005	
Passenger cars			
Gasoline fueled	0.86	0.52	0.61
Hybrid	0.50	0.50	0.50
LPG fueled	0.86	0.52	0.61
Diesel fueled	0.90	0.70	0.75
Trucks			
Gasoline fueled small	0.92	0.77	0.81
Diesel fueled small	1.00	1.00	1.00
Diesel fueled large	0.97	0.91	0.93
Buses			
Gasoline fueled small	0.92	0.77	0.81
Diesel fueled small	1.00	1.00	1.00
Diesel fueled large	0.97	0.91	0.93

* 1990=1.0 smaller is better ** in 2010

5.2 Prospects for Reduction of Energy Input per Unit Output

An analysis of energy conservation technologies was made for automobiles, which account for 90% of CO_2 emissions in the transportation sector, but not for other means of transport. The relative energy efficiency (1990 = 1.0, smaller is better) of automobiles newly sold in 2005 and in 2010 was set according to automobile type as shown in Table 9. Next, the relative energy efficiency of automobile stocks in 2010 was calculated, assuming an average use-life of 10 years for the automobiles. The results in Table 9 were obtained.

5.3 Estimation Results For Each Scenario

The results of estimation for each scenario are shown in Figure 4. The breakdown of differences in CO_2 emissions between Scenarios 0 and 1 are as shown in Table 10.

Table10 : Reduction potentials in transportation sector

	[1000 ton-C]
Gasoline Passenger: Conv.	6,657
Gasoline Passenger: Hybrid	6,053
Gasoline Small Truck	1,937
Diesel Passenger	874
LPG Passenger	820
Diesel Large Truck	791
Diesel Large Bus	67
Total	17,199

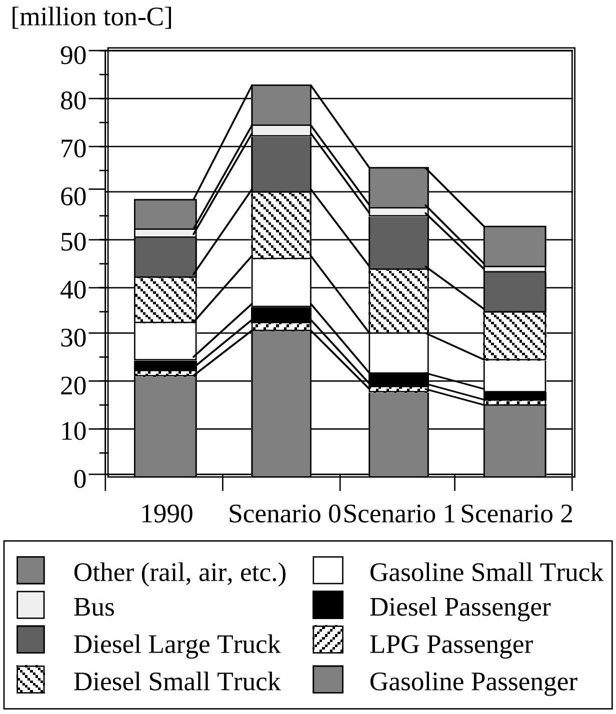


Figure 4 : Estimation results for transportation sector

6. Residential Sector

6.1 Analysis of Energy Demand Structure and Setting of Activity Level

The energy demand structure in the residential sector was analyzed, and broken down into the factors shown in Equation 3:

*Number of households * Σ energy consumption per household for each application * energy consumption efficiency….3)*

The same estimate for number of households was used in Scenarios 0-4 (2010), and differences in activity level were derived from the energy demand per household. The activity level for each scenario was as shown in Table 11. Estimates (median values) by governmental research institutes were used as estimates of the number of households in 2010. Activity levels for each application were estimated, and differences in the fuel composition were accounted for.

6.2 Prospects for Reduction of Energy Input per Unit Output

Energy conservation technologies applicable to the residential sector were identified, and the CO_2 emission reduction per device or household as well as the level of introduction of technologies up to 2010 were estimated to calculate how much energy is conserved with each technology (Table 12). The calculation was made with the assumption that the energy conservation due to each measure/technology was constant regardless of activity level.

6.3 Estimation Results For Each Scenario

The estimation results for each scenario are shown in Table 13.

Table 11 : Trends and prospects of energy consumption per household by end-use type [Gcal/household/year]

Year	Hot water	Heating	Cooking	Cooling	Power etc.
1980	2.81	2.41	1.00	0.08	2.20
1985	3.13	2.95	0.98	0.19	2.46
1990	3.36	2.79	0.97	0.25	3.07
1995	3.53	3.32	0.90	0.27	3.57
1996	3.54	3.13	0.85	0.19	3.70
1997	3.45	3.01	0.83	0.22	3.73
2010	4.29	3.43	0.85	0.31	4.63

Table 12 : Reduction potential in residential sector

	[1000 ton-C/year]
Improved efficiency of heat pump	2,323
Improved efficiency of refrigerator	2,030
Improved eff. of other electric appliances	1,943
Solar system (New)	1,819
Compact fluorescent light	721
Insulation of houses	492
Replacement of stove by heat pump	434
Solar system (Conventional)	288
TV (CRT to LCD)	194
Pair-glass	163
Total	10,407

Table 13 : Estimation results for residential sector

Scenario	CO_2 emission [million ton-C]	Changes from 1990
1990	37.6	0%
Scenario 0	60.8	+62%
Scenario 1	50.9	+35%
Scenario 2	38.0	+1%

* Emission factor for electricity is fixed at 1990 level.

7. Commercial Sector

7.1 Analysis of Energy Demand Structure and Setting of Activity Level

The energy demand structure in the commercial sector was analyzed, and broken down into the factors shown in Equation 4:

*Floor space * Σ energy consumption per floor space for each application * energy consumption efficiency…4)*

The same values were used for estimates of floor space in Scenarios 0 through 4 (2010), and differences in activity level were derived from the energy demand per floor space. The activity level for each scenario is as shown in Table 14. The estimate of floor space in 2010 was set on the basis of past trends, assuming that the rate of increase will slow down somewhat. Estimates of energy demand in the 2010 BAU case were made based on past energy demand growth rates for each application.

7.2 Prospects for Reduction of Energy Input per Unit Output

Energy conservation technologies applicable to the commercial sector were identified, and the energy conservation rate as well as the level of introduction of technologies up to 2010 were estimated to calculate the reduction in energy consumption due to each technology (Table 15).

7.3 Estimation Results For Each Scenario

The estimation results for each scenario are shown in Table 16.

Table 14 : Trends and prospects of energy consumption per floor-space by end-use type [Mcal/m^2/year]

Year	Power etc.	Heating	Hot water	Cooking	Cooling
1980	63.0	101.3	84.7	15.6	13.5
1985	74.7	80.0	70.4	16.3	17.2
1990	92.4	80.7	66.9	17.9	22.2
1995	105.9	74.8	66.1	20.4	21.2
1996	108.3	69.5	64.3	21.2	19.7
1997	109.6	68.0	63.2	21.2	21.0
2010	141.8	59.7	59.2	27.4	21.0

Table 15 : Reduction potential in commercial sector

	[1000 ton-C/year]
Energy-efficient newly-constructed buildings	5,198
Improved efficiency of heat pump (Air-conditioner)	3,708
Improved efficiency of boiler (for hot water)	374
High-frequency fluorescent light	1,587
Task-ambient lighting	702
Computer (Desktop -> Notebook)	730
Insulation of vending machines	249
Improved efficiency of other electric appliances	929
Total	13,477

Table 16 : Estimation results for commercial sector

Scenario	CO_2 emission [million ton-C]	Changes from 1990
1990	33.9	0%
Scenario 0	59.4	+75%
Scenario 1	46.6	+37%
Scenario 2	30.7	-9%

* Emission factor for electricity is fixed at 1990 level.

8. Waste Management Sector

8.1 Prospects for Waste Generation

Waste generation in the 2010 BAU case was estimated from past trends to obtain the results in Table 17. Only CO_2 emissions from combustion of waste plastic and waste oil were calculated, and those from other wastes were not included.

The amount of waste plastic generated was about 7 million tons, which is more than the amount of waste plastic (1.3 million tons) used as a substitute for coal in the iron and steel sector. (All CO_2 emissions from waste plastic used in the iron and steel industry were accounted for in the waste management sector. They were not treated as emissions of the iron and steel sector.)

8.2 Prospects for Introduction of Waste Power Generation

Introduction of waste power generation was estimated to be as shown in Table 18.

Table 17 : Trends and prospects of Municipal Solid Waste

Year	Amount [1000ton]	Share by treatment types Incineration	Recycle etc.	Direct landfill
1980	43,950	60.4%	2.5%	37.1%
1985	43,470	70.6%	3.0%	26.4%
1990	50,440	74.4%	5.2%	20.4%
1995	50,690	76.2%	12.3%	11.5%
1996	51,100	77.1%	12.6%	10.3%
2010	59,100	80%	15%	5%

Table 18 : Parameters for waste power generation

Scenario #	Amount incinerated [1000 ton]	Calorific value [kcal/kg]	Diffusion rate for WPG conv*	new**
1990	37,522	2,179	19%	0%
Scenario0	47,271	2,179	65%	15%
Scenario1	47,271	2,179	40%	40%
Scenario2	44,990	2,216	40%	40%
Scenario3	42,130	2,136	40%	40%
Scenario4	37,799	1,994	40%	40%

* Conventional technology: thermal efficiency at 10%
** Highly efficient technology: thermal efficiency at 20%

9. Energy Conversion Sector

9.1 Emissions from the Energy Conversion Sector

The energy conversion sector includes electric power companies, in-house power generation, heat suppliers, city gas manufacture, coke manufacture, petroleum refining, energy consumption within the energy conversion sector, and power transmission/distribution loss. With regard to CO_2 emissions due to heat suppliers and consumption within the energy conversion sector, the emission levels of fiscal 1990 were used as the emission levels for each of the scenarios. CO_2 emissions due to manufacture of city gas and coke were included in emissions due to use of the final products (city gas and coke). Specifically, an emissions factor which takes account of CO_2 emissions at the time of energy conversion was defined for city gas and coke. CO_2 emissions from petroleum refining were considered to be nil on the assumption that all carbon in input materials is retained in the final product. Emissions due to in-house power generation were calculated as emissions from each of the final demand sectors in which in-house power generation is carried out. The emissions factor for fiscal 1990 was used to calculate such emissions.

Electric power companies and power transmission / distribution loss are dealt with in the following sections.

Table 19 : Maximum capacity of renewable powers in 2010

Type of renewable energy		[million kWh]
Solar photovolatic	for House	137,070
	for Non-house	19,900
Wind		5,809

* source : Environment Agency(1992) : Handbook of mitigation technologies for global warming 5

Table 20 : Thermal efficiencies of power plants based on fossil fuels

Plant type	1990	2010
Coal	38.75%	43.75%
Oil	38.39%	43.39%
Existing LNG	38.94%	43.94%
New LNG	38.94%	46.94%

9.2 Emissions by Electric Power Companies

Emissions by electric power companies were calculated by the following procedure:

1) calculation of required power generation (=demand + transmission/distribution loss + power consumed by the power plant)

2) Calculation of power generated from each power source

3) Calculation of fuel consumption

4) Calculation of CO_2 emissions due to fuel consumption

<Power consumed by power plant and transmission/distribution loss>

Actual 1995 values were used for the rate of transmission/distribution loss and power consumption by the power plant. These factors were used to calculate the required power generation from the power demand in the final demand sectors.

<Prospects for introduction of renewable energy>

Maximum introduction levels of solar and wind power were set as shown in Table 19.

<Prospects for improvement of power generation efficiency of thermal power plants>

The power generation efficiency of thermal power plants was set as shown in Table 20.

<Composition of power sources in each scenario>

The power source supply systems in each scenario were defined as shown in Table 21.

The electric power input per unit output in 1995 was used in Scenario 0.

In Scenario 1, it was assumed that renewable energy (hydropower, geothermal, and new energy) is first used, and the remaining demand which cannot be met with renewable energy is satisfied using nuclear and thermal power. It was assumed that renewable energy would be introduced according to government plans. The proportion of nuclear power to thermal power was assumed to be the same as government projections. The efficiency of thermal power generation was estimated to increase as shown in Table 20.

In Scenarios 2 through 4, it was assumed that renewable energy (hydropower, geothermal, and new energy) is first used, and the remaining demand which cannot be met with renewable energy is satisfied using other power sources, in the order of lowest CO_2 emissions per unit of electric power (nuclear, new LNG thermal, existing LNG thermal, existing petroleum thermal, and existing coal thermal power, in this order). As for renewable energy, the maximum wind and solar power introduction levels were set for the respective scenarios at 1/4, 1/2 or 1/1 of the maximum introduction levels in Table 19. Nuclear power generation was calculated on the assumption that construction of new nuclear reactors will be stopped and existing nuclear reactors will be decommissioned after 30 years of operation. The efficiency of thermal power generation was estimated to increase as shown in Table 20.

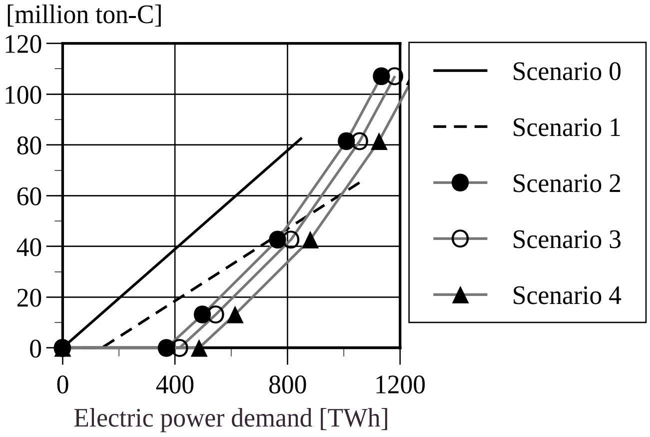


Figure 5 : CO_2 emissions - power demand response curve

<Calculation results of emissions in each scenario >

The CO_2 emissions - power demand response curve for each scenario is shown in Figure 5.

Table 21 : Composition of energy sources for electric power generation

Capacity[10^9kWh] / (Priority)

Type of energy	1990	Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Waste power generation	0.6 (1)	4.6 (1)		4.6 (1)	4.6 (1)	4.6 (1)
Solar photovolatic	0.0 (1)	0.0 (1)	9.0 (1)	44.2 (1)	88.5 (1)	157.0 (1)
Wind	0.0 (1)	0.0 (1)		2.9 (1)	5.8 (1)	5.8 (1)
Hydro	85.4 (1)	79.2 (1)	119.0 (1)	119.0 (1)	119.0 (1)	119.0 (1)
Geothermal	1.5 (1)	2.9 (1)	12.0 (1)	12.0 (1)	12.0 (1)	12.0 (1)
Nuclear	201.4 (1)	289.9 (1)	480.0 (2)	187.3 (2)	187.3 (2)	187.3 (2)
New LNG	0.0 (1)	0.0 (1)	0.0 (2)	128.0 (3)	128.0 (3)	128.0 (3)
Existing LNG	162.0 (1)	185.3 (1)	213.0 (2)	267.5 (4)	267.5 (4)	267.5 (4)
Oil	109.6 (1)	155.3 (1)	87.0 (2)	244.7 (5)	244.7 (5)	244.7 (5)
Coal	73.5 (1)	134.1 (1)	136.0 (2)	124.7 (6)	124.7 (6)	124.7 (6)