In Japan subsidies are provided to the heat pump water heater Eco Cute. The budget of such subsidies is disbursed from the account involved in the development of power sources. The Japanese Ministry of Economy, Trade and Industry appropriated funds for "Leveling of Electric Power Demand" as one of the "Important Matters Related to Nuclear Energy." (This is because it is necessary to subsidize the practical application of high-efficiency water heaters (CO_2 refrigerant heat pump water heaters) and promote the widespread use thereof, which have a large effect of leveling electric power demand day and night, rather than utilizing nighttime power with modest supply and demand, in order to promote efficient utilization of base power sources such as nuclear power generation as the load leveling of electric power demand is a big challenge.)

This load leveling effect is simply described as follows. As one unit of Eco Cute consumes 1 kW of electricity, if 20 million units thereof come into wide use, midnight loads increase by 20 GW and the availability factor (load factor) of electric power equipment as a whole increases.

The point that attention should be paid to here is that, in addition to mere improvement of availability factors of equipment at light load during nighttime, there is an effect of increasing the ratio of nuclear power and that of non-fossil fuels to generated energy, i.e., a large effect of improving the CO_2 emission intensity of electric power, because if additional nuclear power plants equivalent to 20 GW are constructed, these plants can also be operated during daytime when Eco Cute is not operated. In other words, fossil fuels in energy utilization on the demand side are replaced (electrification and utilization of heat in the air by heat pumps), and the effects of replacing fossil fuels and reducing carbon in primary energy on the supply side are yielded at the same time.

Like this, heat pumps can yield the effects of drastically reducing the consumption of imported fossil fuels by "utilizing ambient heat" as a pure domestic resource, expanding the scope of development of nuclear power as a base load through load leveling of electric power, etc. The increased utilization of such heat pumps is expected to create a virtuous cycling of encouraging the demand side to casually use heat pumps just because "they are convenient" and "they are clean," and unwittingly reinforcing energy security of society at large. Moreover, heat pumps also contribute to effective utilization of renewable energy, too. It can be said that the combination of heat pumps, which do not cause the power generation side to produce CO_2, provide high energy utilization rates on the user side and emit no CO_2, is a very effective system as a measure against global warming, which produces no CO_2. Though current situation related to heat pumps by using examples in Japan is outlined here, they can be applied not only to Japan but also to almost every country.

2
CO_2 Reduction by Heat Pumps

CO_2 Reduction Potential of Japan

How much emissions of CO_2 produced by energy consumption can be reduced by heat pumps as a whole? The estimation of potential CO_2 emission reductions in Japan is introduced as follows.

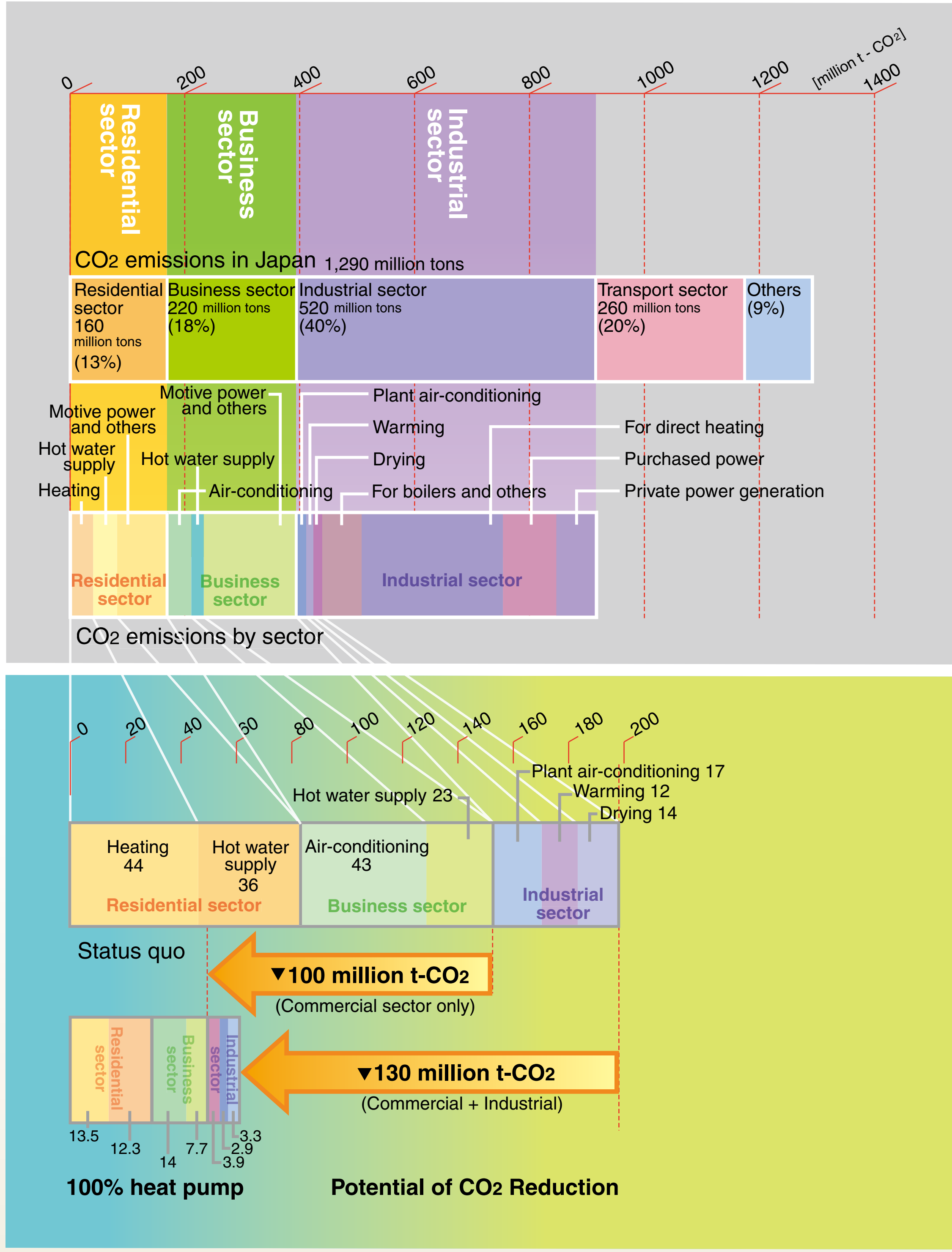
Japan's CO_2 emissions now total about 1,300 million t-CO_2. Of this total, the industrial sector accounts for nearly a half, and the commercial(business and residential sectors) and transport sectors account for the remaining half. However, the comparison of growth rates of CO_2 emissions by sector from fiscal 1990 through fiscal 2004 shows that CO_2 emissions in the industrial sector decreased by 3.3% but CO_2 emissions in the business sector increased by 38.4%, that in the residential sector by 32.3% and that in the transport sector by 20.7%. CO_2 emissions in the commercial sector and transport sector have remarkably increased.

As for further details of composition of energy consumption in the commercial sector, heat demand such as heating and cooling and hot water supply accounts for about two-thirds in the residential sector. Similarly, heating and cooling and hot water supply account for more than 50% in the business sector, too.

This heat demand is mainly satisfied by heat energy, which is still generated by combustion of fossil fuels, representing a major cause of increase in CO_2 emissions.

The potential CO_2 emission reductions by meeting such heat demand with heat pumps instead of fossil fuel-combustion equipments in Japan as a whole amounts to about 100 million t-CO_2 in the commercial sector and about 30 million t-CO_2 in the industrial sector, for a total of about 130 million t-CO_2, which accounts for about 10% of Japan's total CO_2 emissions of about 1.3 billion t-CO_2.
[see. Figure 2.1 Table2.1]

The details of the estimation for each sector showed the following results:



Source: Greenhouse Gas Inventory, based on data quoted from CGER-Report 2004, Ministry of the Environment
Handbook of Energy and Economic Statistics in Japan, 2004 and 2006 Editions, based on data of FYs 2002 & 2004, The Institute of Energy Economics, Japan Survey of Oil Consumption Structure by Sector, 2001 Edition, Ministry of Economy, Trade and Industry

Figure 2.1 Potential of Reducing CO_2 Emissions by Heat Pumps

① Residential Sector

(Heating)

As for the potential CO_2 emission reductions in houses, it is possible to reduce the present estimated CO_2 emissions from heating of 44 million t-CO_2 per year to 13.5 million t-CO_2 per year, representing a potential of reduction by 30.5 million t-CO_2 per year on the assumption that heating by conventional equipment in cold climate areas is replaced with heat pump heaters of COP = 3 and that in general areas with heat pump air-conditioners of COP = 6. [see. Figure 2.2]

(Hot water supply)

On the assumption that conventional water heaters are totally replaced with heat pump water heaters of COP = 4, the present estimated CO_2 emissions of 36 million t-CO_2 per year can be reduced to 12.3 million t-CO_2 per year, representing a potential of reduction by about 23.7 million t-CO_2 per year. [see. Figure 2.3]

② Business Sector

(Air-conditioning)

As for the potential CO_2 emission reductions in buildings for business purposes such as office buildings, stores, etc., the present estimated CO_2 emissions from air-conditioning of 43 million t-CO_2 per year can be reduced to 14 million t-CO_2 per year, representing a potential of reduction by about 29 million t-CO_2 per year, on the assumption that air-conditioners of COP = 6 come into widespread use.
[see. Figure 2.4]

(Hot water supply)

On the assumption that conventional water heaters are totally replaced with heat pump water heaters of COP = 4, the present estimated CO_2 emissions of 23 million t-CO_2 per year can be reduced to 7.7 million t-CO_2 per year, representing a potential of reduction by about 15.3 million t-CO_2 per year. [see. Figure 2.5]

Commercial Sector (= ① + ②)

As mentioned above, the commercial sector alone has a potential of reduction by about 100 million t-CO_2 per year. This figure represents a potential that far exceeds the target to reduce CO_2 emissions of energy origin by about 60 million t-CO_2, which was assigned to the commercial sector under the Kyoto Protocol Target Achievement Plan (decided by the Cabinet of Japan in April 2005).

		Present CO_2 emissions 1	CO_2 emissions after totally replaced by heat pumps 2	Potential of CO_2 reduction 3 = 1 - 2	
① Residential	Heating	44	13.5	30.5	Commercial 100 million tons
	Hot water supply	36	12.3	23.7	
	(Subtotal)	80	25.8	54.2	
② Business	Air-conditioning	43	14	29	
	Hot water supply	23	7.7	15.3	
	(Subtotal)	66	21.7	44.3	
③ Industrial	Plant air-conditioning	17	3.9	13.1	Industrial 30 million tons
	Warming	12	2.9	9.1	
	Drying	14	3.3	10.7	
	(Subtotal)	43	10.1	32.9	
	Total	189	57.6	131.4	

[million t - CO_2]

Table 2.1 Potential of Reducing CO_2 Emissions by Heat Pumps in Japan

③ Industrial Sector

The CO_2 emissions in the industrial sector have remained almost unchanged since 1990, but this sector involves many heating fields where fossil fuels are directly burnt. As for the demand that can be met by heat pumps at present in such heating fields, plant air-conditioning, warming and drying at lower than 100℃ by boilers are realistic.

As for plant air-conditioning, the present estimated CO_2 emissions of 17 million t-CO_2 per year can be reduced to 3.9 million t-CO_2 per year, presenting a potential of reduction by about 13.1 million t-CO_2 per year.

As for warming, the present estimated CO_2 emissions of 12 million t-CO_2 per year can be reduced to 2.9 million t-CO_2 per year, presenting a potential of reduction by about 9.1 million t-CO_2 per year.

As for drying at lower than 100℃, the present estimated CO_2 emissions of 14 million t-CO_2 per year can be reduced to 3.3 million t-CO_2 per year, representing a potential of about 10.7 million t-CO_2 per year.

All together, there is a potential of reduction by about 32.9 million t-CO_2 in the industrial sector.
[see. Figure 2.6]

Figure 2.2

Potential of Reducing CO_2 Emissions from Residential Heating in Japan

Energy Consumption by Residential Heating*1
155,350 million Mcal per year

LPG*1	Kerosene*1	City gas*1
6.7%	64.8%	18.7%
10,460 million Mcal	100,690 million Mcal	29,000 million Mcal

*1<Source> Handbook of Energy and Economic Statistics in Japan, 2005 Edition (values in fiscal 2002)

Others*1 0.0% 100 million Mcal

Electric power*1 9.7% 15,100 million Mcal

- ○ As for LPG heaters, the efficiency of LPG combustion type is assumed at η0.75.
- ・ CO_2 emissions: 10,460 (million Mcal) x 0.250 (t-CO_2/1,000 Mcal) = 2.61 million t-CO_2 per year
- ○ As for kerosene heaters, the efficiency of kerosene combustion type is assumed at η0.75.
- ・ CO_2 emissions: 100,690 (million Mcal) x 0.284 (t-CO_2/1,000 Mcal) = 28.6 million t-CO_2 per year
- ○ As for city gas heaters, the efficiency of city gas combustion type is assumed at η0.75.
- ・ CO_2 emissions: 29,000 (million Mcal) x 0.215 (t-CO_2/1,000 Mcal) = 6.23 million t-CO_2 per year
- ○ As for electric heaters, the efficiency of heater is assumed at η1.0 and that of heat pump air-conditioner at COP6.0.
- ・ CO_2 emissions: 15,100 (million Mcal) / 860 (Mcal/MWh) x 0.378 (t-CO_2/MWh) = 6.64 million t-CO_2 per year

Therefore, the present CO_2 emissions amount to about
44 million t-CO_2 per year (a)
(excluding others)

*The efficiency of combustion type heaters is referred to the BL accreditation criteria.
*The CO_2 emission intensity is based on the Enforcement Ordinance of the Law Concerning the Promotion of Measures to Cope with Global Warming (revised in December 2002)

In the case where combustion-based heaters (η 0.75) are totally shifted to heat pump air-conditioners

Amount of heating demand 105,110 million Mcal | Combustion loss

η=0.75

LPG, kerosene and city gas consumption: 140,150 million Mcal

Heat pump air-conditioner

Amount of heating demand 105,110 million Mcal

Energy consumption 21,890 million Mcal

COP = 6.0 (4.0 in cold climate areas)

CO_2 emissions in the case of shift to heat pump air-conditioners
21,890 million Mcal / 860 (Mcal/MWh)
x 0.378 (t-CO_2/MWh)
= 9.63 million t-CO_2 per year **(b)**

In the case where electric heaters (η 1.0) are totally shifted to heat pump air-conditioners

Amount of heating demand 7,550 million Mcal

Energy consumption: 7,550 million Mcal

It is assumed that heaters account for half of the heating demand for electric power

Heat pump air-conditioner

Amount of heating demand 7,550 million Mcal

Energy consumption 1,260 million Mcal

COP = 6.0

CO_2 emissions in the case of shift to heat pump air-conditioners
8,810 million Mcal / 860 (Mcal/MWh)
x 0.378 (t-CO_2/MWh)
= 3.87 million t-CO_2 per year **(c)**

Potential CO_2 emission reductions by introduction of heat pump air-conditioners
a - (b+c) = about 30.5 million t-CO_2 per year

Figure 2.3

Potential of Reducing CO_2 Emissions from Residential Hot Water Supply in Japan

Energy Consumption by Residential Hot Water Supply*1
148,980 million Mcal per year

LPG*1	Kerosene*1	City gas*1
29.1%	25.6%	33.1%
47,350 million Mcal	33,810 million Mcal	52,330 million Mcal

*1<Source> Handbook of Energy and Economic Statistics in Japan, 2005 Edition (values in fiscal 2002)

Others*1 5.7% 7,330 million Mcal

Electric power*1 6.3% 8,160 million Mcal

- ○ As for LPG water heaters, the efficiency of LPG combustion type is assumed at η0.78.
- ・ CO_2 emissions: 47,350 (million Mcal) x 0.250 (t-CO_2/1,000 Mcal) = **11.84 million t-CO_2 per year**
- ○ As for kerosene water heaters, the efficiency of kerosene combustion type is assumed at η0.78.
- ・ CO_2 emissions: 33,810 (million Mcal) x 0.284 (t-CO_2/1,000 Mcal) = **9.6 million t-CO_2 per year**
- ○ As for city gas water heaters, the efficiency of city gas combustion type is assumed at η0.78.
- ・ CO_2 emissions: 52,330 (million Mcal) x 0.215 (t-CO_2/1,000 Mcal) = **11.25 million t-CO_2 per year**
- ○ As for electric water heaters, the efficiency of electric water heater is assumed at 0.9.
- ・ CO_2 emissions: 8,160 (million Mcal) / 860 (Mcal/MWh) x 0.378 (t-CO_2/MWh) = **3.59 million t-CO_2 per year**

Therefore, the present CO_2 emissions amount to about
36 million t-CO_2 per year (excluding others) **(a)**

*The efficiency of combustion type water heaters is referred to the BL accreditation criteria.
*The CO_2 emission intensity is based on the Enforcement Ordinance of the Law Concerning the Promotion of Measures to Cope with Global Warming (revised in December 2002)

In the case where combustion-based water heaters (η0.78) are totally shifted to heat pump water heaters (COP4.0)

Amount of water heating demand 104,120 million Mcal | Combustion loss

η=0.78

LPG, kerosene and city gas consumption: 133,490 million Mcal

Heat pump water heater

Amount of water heating demand 104,120 million Mcal

Energy consumption 26,030 million Mcal

COP = 4.0

CO_2 emissions in the case of total shift to COP4.0 water heaters 26,030 million Mcal / 860 (Mcal/MWh)
x 0.378 (t-CO_2/MWh)
= 11.44 million t-CO_2 per year **(b)**

In the case where electric water heaters (COP0.9) are totally shifted to heat pump water heaters (COP4.0)

Amount of heating demand 7,340 million Mcal

Energy consumption: 8,160 million Mcal

Heat pump water heater

Amount of water heating demand 7,340 million Mcal

Energy consumption 1,840 million Mcal

COP = 4.0

CO_2 emissions in the case of total shift to COP4.0 water heaters 1,840 million Mcal / 860 (Mcal/MWh)
x 0.378 (t-CO_2/MWh)
= 0.81 million t-CO_2 per year **(c)**

Potential amount of reduction in CO2 emissions by introduction of heat pump water heaters a - (b+c) = 23.7 million t-CO2 per year

Figure 2.4

Potential of Reducing CO_2 Emissions from Air-Conditioners for Business Use in Japan

Energy Consumption by Air-Conditioners for Business Use*1
141,800 million Mcal per year

Oil*1	Gas*1	Electric power*1
60.7%	15.8%	22.3%
85,670 million Mcal	22,260 million Mcal	31,960 million Mcal

*1<Source> Handbook of Energy and Economic Statistics in Japan, 2005 Edition (values in fiscal 2002)

Others*1
1.2%
1,910 million Mcal

○ As for oil-based air-conditioners, the efficiency of kerosene combustion type is estimated at η0.9.
・CO_2 emissions: 85,670 (million Mcal) x 0.284 (t-CO_2/1,000 Mcal) = **24.33 million t-CO_2 per year**
○ As for gas-based air-conditioners, the efficiency of city gas combustion type is assumed at η0.9.
・CO_2 emissions: 22,260 (million Mcal) x 0.215 (t-CO_2/1,000 Mcal) = **4.79 million t-CO_2 per year**

○ As for electric air-conditioners, the efficiency of conventional heat pump type is assumed at COP3.
・CO_2 emissions: 31,960 (million Mcal) / 860 (kcal/MWh) x 1,000 x 0.378 (t-CO_2/MWh) = **14.05 million t-CO_2 per year**

Therefore, the present CO_2 emissions amount to about
43 million t-CO_2 per year (a)
(excluding others)

In the case where combustion-based air-conditioners (η0.9) are totally shifted to high-efficiency heat pump air-conditioners (COP6)

Combustion-based air-conditioners

Combustion loss
Amount of air-conditioning demand 97,140 million Mcal
η = 0.9
Oil and gas consumption: 107,930 million Mcal

High-efficiency heat pump air-conditioner

Amount of air-conditioning demand 97,140 million Mcal
Electricity consumption 16,190 million Mcal
COP = 6.0

CO_2 emissions in the case of total shift to COP6 air-conditioners
16,190 million Mcal / 860 (kcal/MWh) x 1,000 x 0.378 (t-CO2/MWh) = 7.12 million t-CO_2 per year **(b)**

In the case where conventional heat pump air-conditioners (COP3) are shifted to high-efficiency heat pump air-conditioners (COP6)

Conventional heat pump air-conditioners

Amount of air-conditioning demand 95,880 million Mcal
Electricity consumption 31,960 million Mcal
COP = 3.0

High-efficiency heat pump air-conditioner

Amount of air-conditioning demand 95,880 million Mcal
Electricity consumption 15,830 million Mcal
COP = 6.0

CO_2 emissions in the case of total shift to COP6 air-conditioners
15,830 million Mcal / 860 (kcal/MWh) x 1,000 x 0.378 (t-CO2/MWh) = 7.02 million t-CO_2 per year **(c)**

Potential amount of reduction in CO_2 emissions by introduction of high-efficiency heat pump air-conditioners a - (b+c) = about 29 million t-CO_2 per year

Figure 2.5

Potential of Reducing CO_2 Emissions from Hot Water Supply for Business Use in Japan

Energy Consumption by Hot Water Supply for Business Use*1
102,360 million Mcal per yearv

Gas*1	Oil*1
34.0%	53.4%
34,790 million Mcal	54,690 million Mcal

*1<Source> Handbook of Energy and Economic Statistics in Japan, 2005 Edition (values in fiscal 2002)

Others*1
12.6%
12,880 million Mcal

○ As for gas-based water heaters, the efficiency of city gas combustion type is assumed at η0.78.
・CO_2 emissions: 34,790 (million Mcal) x 0.215 (t-CO_2/1,000 Mcal) = 7.48 million t-CO_2 per year
○ As for oil-based water heaters, the efficiency of kerosene combustion type is assumed at η0.78.
・CO_2 emissions: 54,690 (million Mcal) x 0.284 (t-CO_2/1,000 Mcal) = 15.53 million t-CO_2 per year

Therefore, the present CO_2 emissions amount to about
23 million t-CO_2 per year (excluding others) **(a)**

In the case where combustion-based water heaters (η0.78) are totally shifted to heat pump water heaters (COP4.0)

Combustion-based water heaters

η=0.78
Combustion loss
Amount of water heating demand 69,790 million Mcal
Gas and oil consumption: 89,480 million Mcal

Heat pump water heaters

Amount of water heating demand 69,790 million Mcal
Electricity consumption 17,450 million Mcal
COP = 4.0

CO_2 emissions in the case of total shift to COP4.0 water heaters
17,450 million Mcal / 860 (kcal/MWh)
x 1,000 x 0.378 (t-CO_2/MWh)
= 7.67 million t-CO_2 per year **(b)**

Potential amount of reduction in CO_2 emissions by introduction of heat pump water heaters (a - b) = about 15.30 million t-CO_2 per year