

ROLE OF ENERGY SUPPLIER FOR HEAT PUMP DEPLOYMENT

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Abstract: Japan's electric power utilities are trying to reduce CO₂ emissions from the viewpoints of both supply and demand side. In the supply side, they are trying to reduce the CO₂ emission rate per electric power consumption mainly by promoting nuclear generation. In the demand side, they are trying to promote widespread use of heat pumps that can greatly contribute to the reduction in CO₂ emissions. For the spread out of heat pumps, it is necessary for the government, researchers, manufacturers, end users and electric power utilities to make united efforts.

Key Words: *Heat pump, nuclear energy, Power sector, CO₂ Reduction*

1 INTRODUCTION

Global warming issues are of great concern in the world and all human beings should be involved, more or less, for resolution. It is necessary not only for developed countries but also for developing countries to take measures in proportion to their levels of capability based on "Common but Differentiated Responsibility." Moreover, as the global warming issues are closely related with economic activities, local communities and the lives of people in general, all parties, including the government, electric power utilities, industries and end users, should participate and cooperate together.

Among others, electric power utilities are responsible to make efforts to reduce CO₂ emissions as a large emitter of CO₂. However, they should aim to achieve simultaneously "economic growth," "energy security" and "environmental protection," following the basic concept of "environmental protection compatible with economic growth." Therefore they must implement measures to reduce CO₂ emissions not only in supply side but also in demand side.

The following equation shows that CO₂ emissions due to electric power consumption are expressed by the product of three terms. The first term on the right side represents the CO₂ emission rate per kilowatt-hour, which could be reduced by the measures taken in supply side. The second term represents electric power consumption rate per activity, which could be reduced by the measures taken in demand side. It can be found that CO₂ emissions can be reduced by decreasing these two terms without decreasing economic and social activities that use electric power, which the third term represent.

One of the most effective measures of reducing CO₂ emission rate per kilowatt-hour is promoting nuclear generation. One of the most effective measures of reducing electric power rate per activity is deploying high-efficiency equipment, especially, heat pumps.

$$\begin{array}{ccccccc}
 \text{CO}_2 \text{ emissions due to} & & & & & & \\
 \text{electric power} & = & \frac{\text{CO}_2 \text{ emissions}}{\Sigma \text{ kWh}} & \times & \frac{\Sigma \text{ kWh}}{\text{Amount of activities}} & \times & \text{Amount of} \\
 \text{consumption} & & \downarrow & & \downarrow & & \downarrow \\
 & & \text{CO}_2 \text{ emission rate} & & \text{Electric power} & & \text{Amount of economic} \\
 & & \text{per kilowatt-hour} & & \text{consumption rate} & & \text{and social activities} \\
 & & & & \text{per activity} & & \text{that use electric power}
 \end{array}$$

This paper introduces the efforts of Japan's electric power utilities to reduce CO₂ emissions in demand side as well as supply side. Depending on situation of economic growth, energy demand and supply situation, climate, culture and living habits, the measures required to reduce CO₂ emissions vary from country to country or region to region.

2 Introduction of Japan's Efforts

2.1 The characteristics of Japan

Japan is an archipelagic country long extending in a north-south direction and ranges of steep mountains run through the country. Japan has unique characteristics in terms of geography and climate.

Mountainous areas account for 75% of the country as a whole, and the area of flatland accounts for only 25%. Particularly in alluvial plains that account for 10% of the country, population has intensively increased, urbanization has intensified, and population and assets have concentrated. Japan has such topographical characteristics.

As for climate, moreover, the ownership rate of air-conditioners is high in Japan because it is hot and humid in summer. The weather in winter is relatively mild, though it varies largely from region to region.

As the characteristics of lifestyles of Japanese people, moreover, we have a habit of filling a bathtub with hot water and enjoy bathing unlike European and American people who mainly take a shower bath.

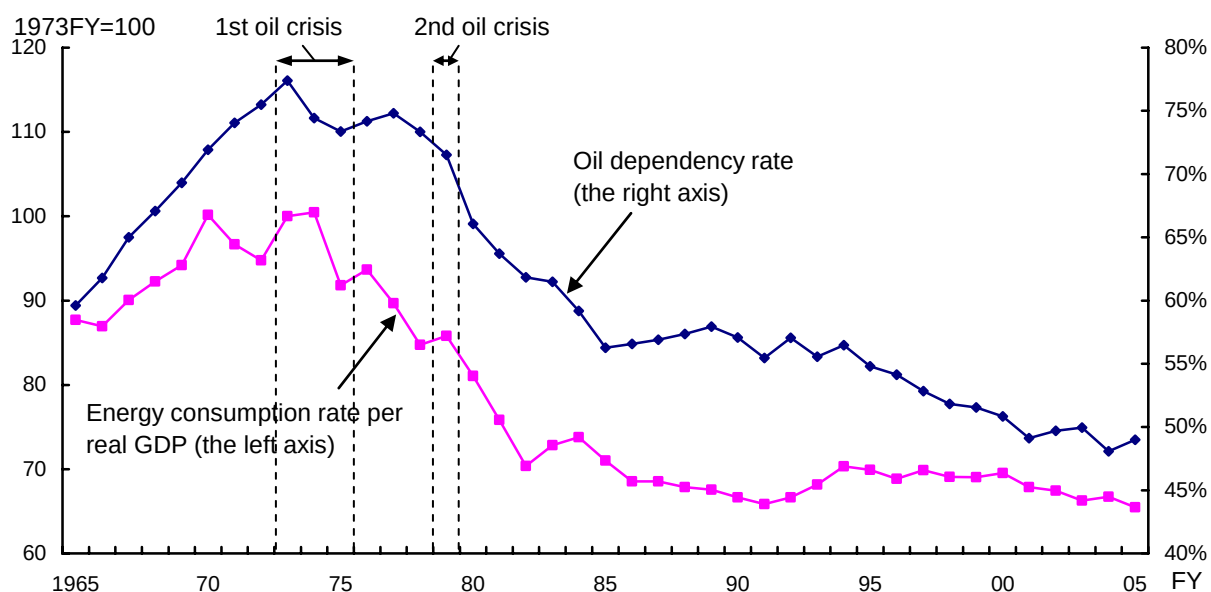
As for energy, Japan depends on imports from overseas as it has almost no domestic energy resources such as oil, natural gas and others. Japan's energy self-sufficiency rate is only 4% that is the lowest level among major developed countries (G8). Unlike North America and Europe, moreover, Japan has no oil, natural pipeline networks nor power transmission lines that are connected across the border to other countries. Therefore, such geographical constraints do not allow Japan to easily import energy from neighboring Asian countries.

2.2 Efforts in Supply Side

2.2.1 Japan's Energy Affairs and Power Generation Mix

Figure 1 shows the changes in Japan's dependency on oil and energy consumption rate per real GDP. In Japan, 77% of energy supply was dependent on oil in 1973. In the wake of two oil crises since then, Japan has promoted the use of alternative energy to oil, and promoted diversification of energy sources such as nuclear energy and natural gas. As a result, Japan's dependency on oil decreased to 49% in 2005.

Moreover, the oil crises changed Japan's industrial structure that shifted from a heavy energy consuming industry to a less energy consuming industry, and also have promoted energy conservation. Japan's energy consumption rate per real GDP in 2005 decreased to about two-thirds of the 1973 level.



Source: Energy Balances in Japan, Annual Report on National Accounts

Figure 1: Changes in Japan's Oil Dependency Rate and Energy Consumption Rate per Real GDP

On the other hand, electricity is easy to use as it is safe and clean. The electricity demand keeps on increasing mainly for residential and business use.

Table 1 shows the comparison of Japan's power generation mix in 2005 and 1980 immediately after the second oil crisis. In 2005, hydroelectric power accounts for 7%, thermal power for 63% and nuclear power for 28%. The share of nuclear power has increased from 1980. This is because Japan has strived to create a well-balanced power generation mix that does not rely on single power source in overall consideration of stability and cost efficiency of electricity supply.

Table 1: Japan's Power Generation Mix by Type of Power Source (Including Non-utility Generation)

Unit: million kWh

	Nuclear power	Hydro-electric power	Thermal power			Others	Total
			Coal	Natural gas	Oil		
1980	82,591 14.4%	88,292 15.4%	49,992 8.7%	81,107 14.2%	269,649 47.1%	900 0.2%	572,531 100.0%
2005	304,760 27.9%	78,210 7.1%	309,330 28.3%	231,380 21.1%	145,990 13.3%	24,520 2.2%	1,094,190 100.0%

Note: The lower figures represent shares in total.

Source: OECD Energy Balances of OECD Countries

2.2.2 Japan's Actual CO₂ Emissions and Share of CO₂ Emissions of Electric Power Utilities

Japan's total greenhouse gas emissions amounted to 1,359 million t-CO₂ in 2005, up 7.7% from the level of 1990 as the base year. Therefore the gap from the 6% reduction commitment in the Kyoto Protocol increased to 13.7%.

This is mainly because the CO₂ emissions of energy origin, which account for about 90% of Japan's greenhouse gas emissions, largely increased by 11.3% from the 1990 level. Table 2 shows CO₂ emissions in breakdown by sector. The emissions from industrial sector that accounts for 35% of the total remain almost unchanged, and the emissions from transport sector that accounts for 20% increased by 18% from the 1990 level but show a slight decline

in recent years, whereas the emissions from business and other sector that accounts for 18% and from residential sector that accounts for 13% increased largely by 45% and 36%, respectively, from the 1990 level.

The emissions from energy conversion sector (self-consumption at power stations and others), which electric power utilities belong to, account for 6% of the total or the lowest level among the five sectors. This is because the CO₂ emissions from power generation are allocated to other four final demand sectors in proportion to their respective power consumption. The emissions from this sector before such allocation account for as large as 30.7% of the total as shown in Figure 2.

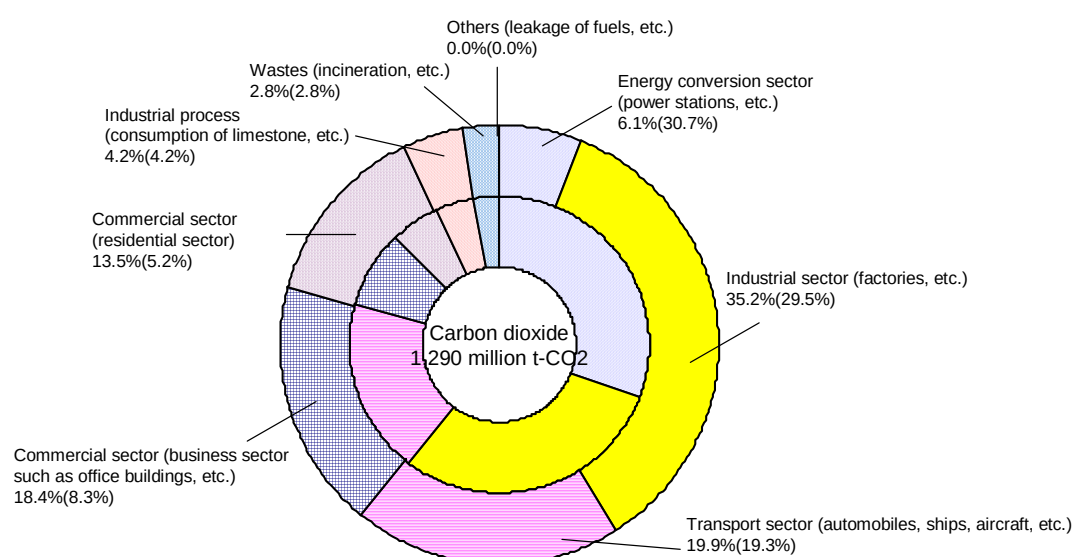
Table 2: CO₂ Emissions in Breakdown by Sector

Unit: million t-CO₂ and %

Sector	CO ₂ emissions of energy origin					CO ₂ emissions of non-energy origin	Total
	Industrial sector	Business and other sector	Residential sector	Transport sector	Energy conversion sector		
1990 (a)	482 42%	164 14%	127 11%	217 19%	68 6%	85 7%	1,144 100%
2005 (b)	452 35%	239 18%	174 13%	257 20%	79 6%	91 7%	1,292 100%
(b-a)/a	-6.1%	+45.4%	+36.4%	+18.1%	+16.5%	+0.7%	+11.3%

Note: The lower figures represent shares in total.

Source: Kyoto Protocol Target Achievement Plan



The outer circle represents the shares of emissions from power generation allocated to the final demand sectors in proportion to their respective power consumption.

The inner circle represents the shares of direct emissions from respective sectors (figures in parentheses).

Note: The total of shares is not necessarily 100% because the figures are rounded off. The indication by percent represents the ratios to total emissions. Others include statistical errors, consumption of lubricating oil, and others.

Source: Data of the Ministry of the Environment

Figure 2: Shares of CO₂ Emissions by Sector (2005)

2.2.3 CO₂ Emissions Reduction Target of Japan's Electric Power Utilities

Japan's electric power utilities are making efforts to reduce their CO₂ emission rate per kilowatt-hour. As shown in Table 3, they set a voluntary target to reduce their CO₂ emission rate per kilowatt-hour by 20% on average from the 1990 level in five years from 2008 through 2012. This target is set in the Nippon Keidanren's Voluntary Action Plan on the Environment together with the targets of other industrial sectors, and periodically evaluated and verified by the government's councils and others.

At present, the average CO₂ emission rate per kilowatt-hour in 2008-2012 is estimated at about 0.37 kg-CO₂ per kWh. As the figure is yet to reach the target, they aim to achieve the target by further strengthening their measures.

Table 3: CO₂ Emissions Reduction Target of Japan's Electric Power Utilities

Unit: kg-CO₂/kWh

	Actual figure in 1990	Actual figure in 2004	Actual figure in 2005	Actual figure in 2006	2008-2012	
					Target	Outlook
CO ₂ emission rate per kilowatt-hour	0.417	0.418	0.423	0.410	About 0.34	About 0.37

Source: The Federation of Electric Power Companies of Japan

2.2.4 Measures for Achievement of the Target -- Promotion of Nuclear Energy

At present, 55 units of nuclear power plants totaling 49.58 million kW are placed in service throughout Japan, accounting for about 30% of total generated energy as principal power sources. The electricity demand is expected to continue to increase in the future. In such circumstances, for Japan as a resource-poor country, nuclear power generation will be the core of alternative energy to oil, which is superior in supply stability and economy. Moreover, nuclear energy, which does not cause CO₂ emissions when it generates electric power, plays a leading role in the measures for reduction in CO₂ emissions. In the "Kyoto Protocol Target Achievement Plan," which is established by the Japanese government, nuclear energy is also very important in promoting measures against global warming and given a position to be steadily promoted by mutual cooperation of the government and private sectors as a principal power source.

Electric power utilities also regard the promotion of nuclear energy as the most important challenge in terms of business management. Under the cooperation with the Japanese government, they will exert their utmost efforts to construct new nuclear power plants and improve the capacity factors of existing nuclear power plants.

2.2.5 Measures for Achievement of the Target -- Development and Diffusion of Renewable Energy

Renewable energy such as photovoltaic power, wind power, geothermal heat, biomass and others causes less environmental loads compared with fossil fuels. Particularly in the Kyoto Protocol, renewable energy is given a position not to produce any greenhouse gas. The use of renewable energy can be expanded without being largely restricted by measures for environmental protection. On the other hand, renewable energy can hardly come into wide use in a self-reliant manner because of economic constraints. So, renewable energy needs policy-based support.

It is made obligatory by law (Renewable Portfolio Standard Law) for Japan's electric power utilities to use electricity generated by renewable energy and others. In 2014, they are required to use 16 billion kWh (about 1.6% of the amount of electricity sold) of such electricity. The target is about four times as much as the obligatory amount set in 2005. they will undertake efforts to achieve the target.

Moreover, Japan's electric power utilities install wind power and photovoltaic power generation equipment on their own, and they purchase surplus electricity generated by the wind power and photovoltaic power generation equipment of customers.

2.2.6 Measures for Achievement of the Target -- Improvement of Thermal Power Generation Efficiency and Reduction in Power Transmission and Distribution Loss Factors

The improvement of thermal efficiency of thermal power generation directly contributes to reduction in CO₂ emission rate per kilowatt-hour. Japan's electric power utilities are engaged in the development and introduction of Advanced Combined Cycle (ACC) power generation that has achieved power generation efficiency of about 53% as well as in the development of high-efficiency coal-fired power generation technology such as Integrated Gasification Combined Cycle (IGCC).

In addition, they are also working to reduce power transmission and distribution loss factors. As shown in Figure 3, Japan's electric power utilities boast the world's top-level thermal power generation efficiency and power transmission and distribution loss factors.

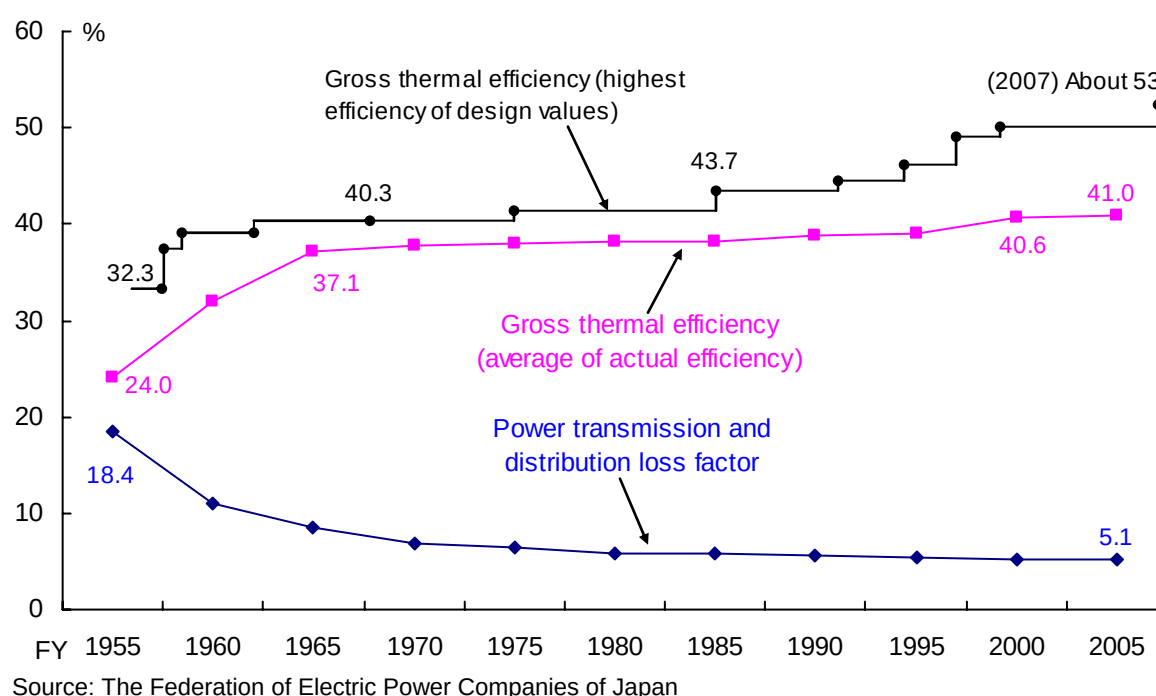


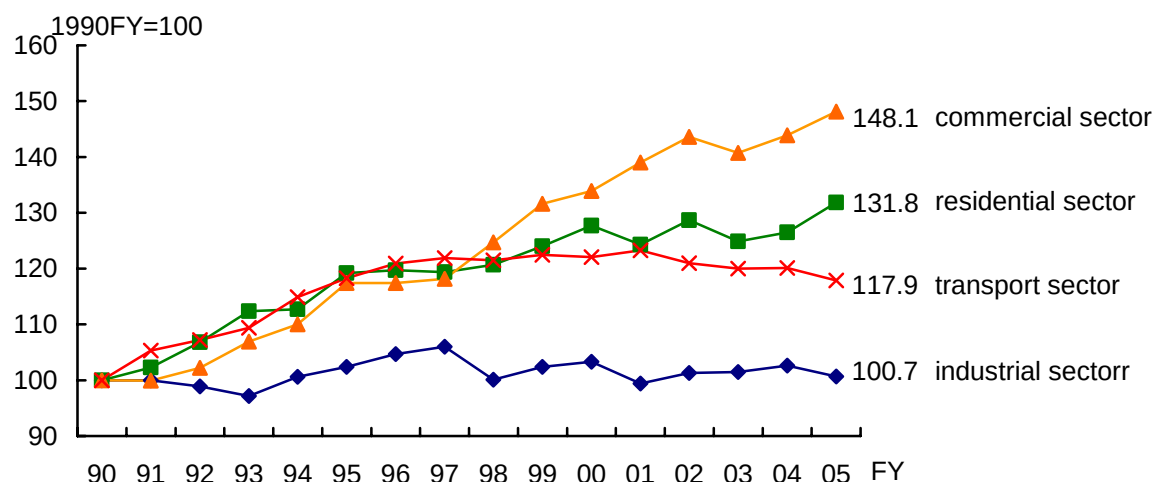
Figure 3: Changes in Thermal Power Generation Efficiency (HHV) and Power Transmission and Distribution Loss Factors

2.3 Efforts in Demand Side

2.3.1 Conditions of Final Energy Consumption in Japan

The industrial sector accounts for nearly half of Japan's final energy consumption, and the commercial sector (the business and residential sectors) and transport sector account for the remaining half. Figure 4 shows the energy consumption trends in breakdown by sector from 1990 through 2005. The energy consumption in the industrial sector increased slightly by 0.7%, whereas the energy consumption in the business sector increased by 48.1%, that in the residential sector by 31.8% and that in the transport sector by 17.9%. Energy consumption significantly increased in the business and residential sectors.

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



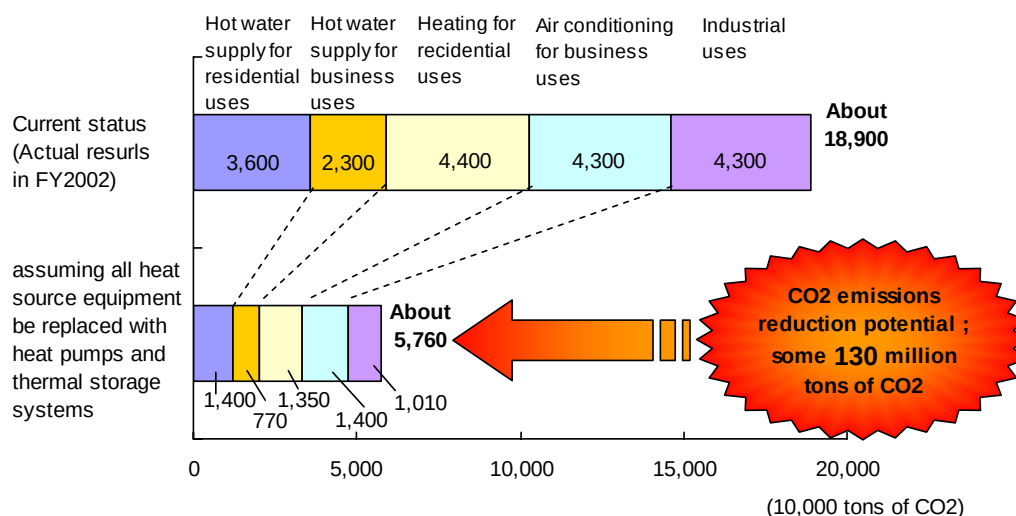
Source: Energy Balances in Japan

Figure 4; Changes in Final Energy Consumption by Sector

2.3.2 Potential of Heat Pumps to Reduce CO₂ Emissions

As for the energy consumption in the commercial sector, heat demand such as heating and cooling and hot water supply directly utilizes the thermal energy produced by combustion of fossil fuels, constituting a major cause of increase in CO₂ emissions. Using heat pumps in this field makes it possible to reduce the consumption of fossil fuels and at the same time to reduce CO₂ emissions.

According to trial calculations by Heat Pump & Thermal Storage Technology Center of Japan, if the burning appliances and others now in use are replaced by high-efficiency heat pump appliances, CO₂ emissions can potentially be reduced by about 100 million tons in the commercial sector and about 30 million tons in the industrial sector, for a total of about 130 million tons, which account for about 10% of Japan's total annual CO₂ emissions.



Source: Heat Pump & Thermal Storage Technology Center of Japan

Figure 5: Effect of Heat Pumps to Reduce CO₂ Emissions

2.3.3 Current Status of Diffusion of Heat Pump Appliances

In the "Kyoto Protocol Target Achievement Plan" established by the Japanese government, a target to diffuse 5.2 million units of CO₂ refrigerant heat pump water heaters, called "Eco Cute" in Japan, by 2010 as a measure to reduce CO₂ emissions mainly in the residential sector is declared. As of the end of 2007, as a result, 1.24 million units came into use, which is equivalent to less than 3% of households. In the business sector, a target to diffuse 1.41 million refrigeration tons of high-efficiency heat pump air conditioners by 2010 is declared, but such air conditioners amounted to only 190,000 refrigeration tons as of the end of 2005. In recent years, heat pump technology has been further innovated, and heat pumps now yield very large effects compared with other energy-saving technologies. As a result, heat pumps have been steadily coming into wide use year after year. To achieve the target, however, further measures to rapidly spread out heat pumps are required.

2.3.4 Efforts of Electric Power Utilities to Diffuse Heat Pump Appliances

Japan's electric power utilities are trying to promote widespread use of highly efficient heat pump appliances through dissemination of information to customers and sales activities to encourage efficient energy utilization in the society. Specifically, they conduct PR activities by utilizing mass media such as TV commercial messages and events to exhibit heat pump appliances. They also provide opportunities to customers to feel familiar to the merits of heat pumps by simulating the energy-saving effects of installation of heat pumps and the effects of reduction in CO₂ emissions on their websites.

In addition to these efforts, employees of electric power companies directly visit the houses of customers and propose heat pump appliances, and also promote sales activities to encourage building and house construction companies to adopt heat pump appliances. They also provide a leasing system and a loan system with preferential interest rate to help customers introduce heat pump appliances, and such systems contribute to a steady increase in the number of heat pump appliances that have come into use.

Furthermore, Japan's electric power utilities have been making suggestions to the government to support diffusion of heat pumps. Consequently, it was realized that the government pays subsidies for installation of a CO₂ refrigerant heat pump water heater (Eco Cute) and a high-efficiency heat pump air conditioner to end users.

Moreover, Japan's electric power utilities have carried out the research and development of heat pump appliances in cooperation with manufacturers. In 2001, they developed a CO₂ refrigerant heat pump water heater (Eco Cute) with an aim to expand the use of heat pumps in the field of hot water supply. They are also engaged in the development to further improve the efficiency of heat pump appliances. As shown in Table 4, the rated COP of CO₂ refrigerant heat pump water heater increased from 3.5 in 2001 to 4.9 in 2006, and that of turbo refrigerator from 6.1 to 6.4. By promoting close cooperation with manufacturers and administration, the electric power utilities plan to reinforce their efforts to expand the applications and further improve efficiency of heat pump appliances

Table 4: Changes in Improvement of Performance of Heat Pumps (Rated COP)

	CO ₂ refrigerant heat pump water heater	Package air conditioner for business use	Turbo refrigerator
2001	3.5	4.0	6.1
2006	4.9	4.5	6.4

Source: Heat Pump & Thermal Storage Technology Center of Japan

3 Conclusion

As for the efforts to be made in supply side, electric power utilities will play a leading role from the standpoint of shouldering the responsibility of energy supply, realize well-balanced power generation mix with nuclear energy, and promote reduction in the CO₂ emission rate per kilowatt-hour.

As for the efforts to be made in demand side, researchers, manufacturers and electric power utilities will try in one to encourage end users to understand the environmental superiority of heat pump appliances and promote widespread use thereof. Moreover, they would like to foster the understanding of the government as policy maker about the usability of heat pump appliances to cope with the global warming issues (CO₂ emissions reduction) and ask for establishment of policy-based measures to promote widespread use of heat pump appliances.

Widespread use of heat pumps that have a large potential of reducing CO₂ emissions is one of the break through for reduction in CO₂ emissions to solve the global warming issues. For the widespread use of heat pump appliances, it is important for the government, researchers, manufacturers, end users and electric power utilities to make integrated efforts.

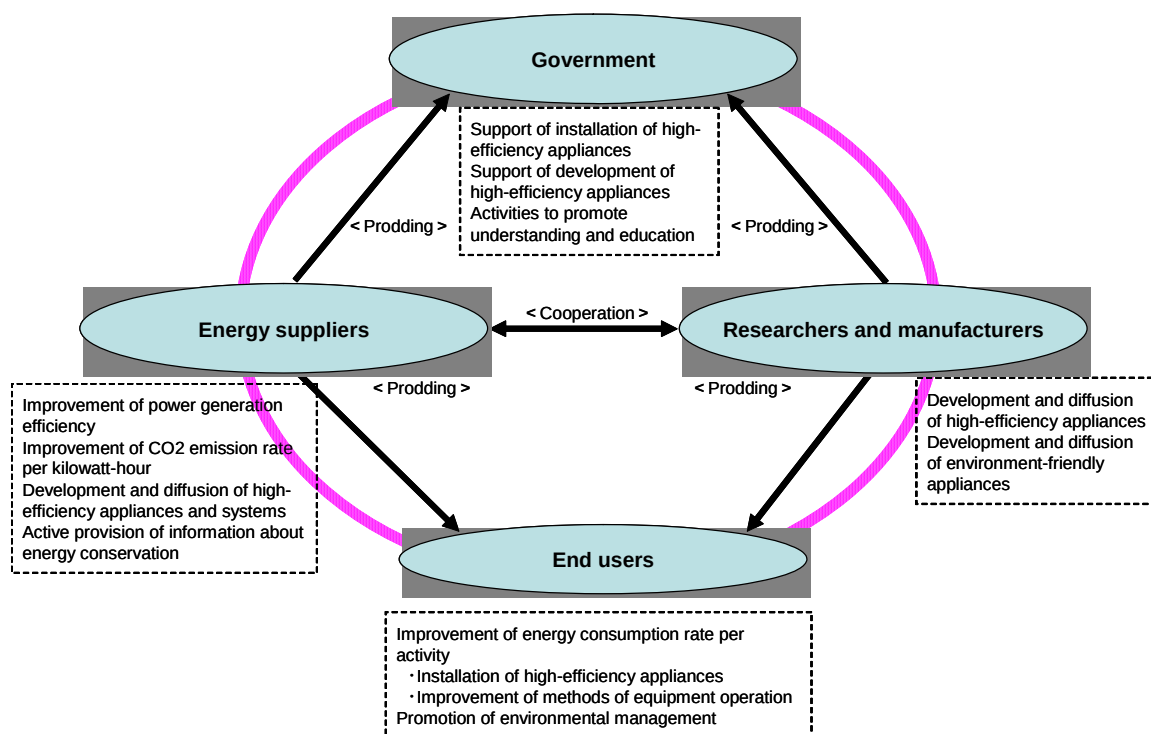


Figure 6: Image of Cooperation among Parties Concerned to Promote Reduction in CO₂ Emissions by Heat Pumps