1

Heat Pumps contribute to Environmental Protection and Energy Security

Global Environmental Protection by Heat Pumps

It is almost concluded that global warming is caused by greenhouse gases that are emitted by human activities, and the largest cause of global warming is the emission of carbon dioxide (CO_2) produced by energy consumption. Realistic measures to stop the increase in CO_2 in the atmosphere are to increase the area of forests to absorb CO_2 or to reduce the consumption of fossil fuel energy as an emission source of CO_2 and make efforts for doing without carbon.

The applications of fossil fuels used as energy, moreover, can be roughly classified into the case where they are burnt by customers as the primary energy to produce the heat energy required for power and heating and cooling, and the case where they are burnt to generate electricity (secondary energy) to be used by customers. In either case, effective measures for CO_2 reduction are to reduce energy consumption itself such as improvement of efficiency of energy utilization and shift to low-carbon energy sources.

From the viewpoint of reduction in CO_2 emissions of energy origin, which have such characteristics, considerations are given to what roles can be played by heat pumps.

First, in the field of heat utilization, heat pumps are a mechanism to convert unused "ambient heat" into heat of utilizable temperatures by inputting a very small amount of primary energy without burning fuels as a source of CO_2 emissions.

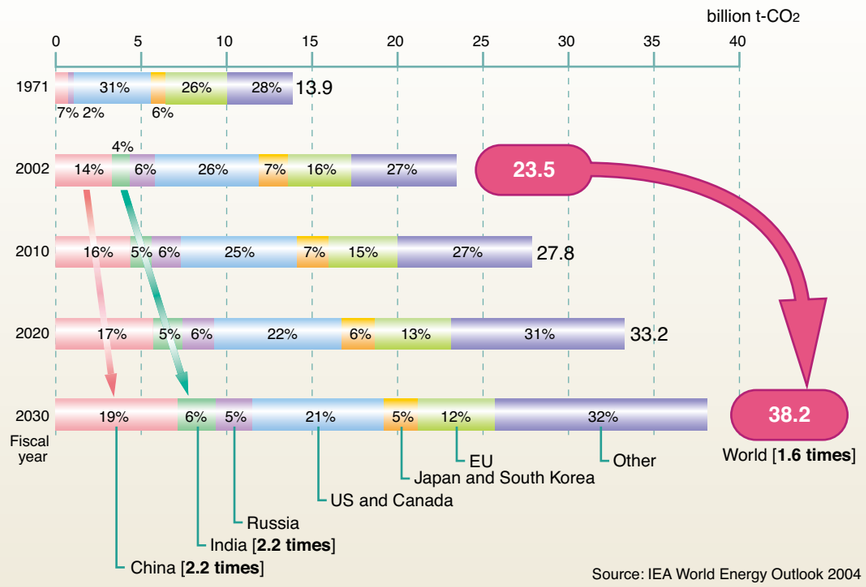


Figure 1.1 Changes in and Prospects for CO_2 Emissions of Energy Origin in the World by Region

Shifting to such heat utilized by heat pumps has the significance of shifting the energy source to utilize heat from direct combustion of "fossil fuels" to "electric power," a large part of which is generated by non-fossil fuels. Such shift, moreover, has the significance of fully utilizing the ambient heat (inexhaustible, renewable and no CO_2 emission) that occurs in the natural world and using only a small amount of electric power to produce heat, instead of using the heat of combustion of fossil fuels (the efficiency of utilization is 100% at the maximum in the case of high temperatures).

In the case where such heat pumps fully come into wider use in the air-conditioning and hot water supply fields, there estimated to be a potential of reducing Japan's CO_2 emissions by about 10%. No other technology can make such a large-scale contribution as a single technology to reduction in greenhouse gas emissions.

Moreover, it should be also very significant that heat pumps are the technology that has been already established. For example, there is a technique called CCS (Carbon Dioxide Capture and Storage) to recover CO_2 emitted from the flues of thermal power stations into the atmosphere and store CO_2 in strata.But this technique still has many problems yet to be cleared including, among others, environmental impact assessments, monitoring methodologies, effectiveness of measures, costs, selection of storage sites, international agreement, etc.Similarly, fuel cells that provide combined heat and power generation (CHP) through chemical combination of hydrogen with oxygen now still depend on the fossil fuel reforming technique that produces CO_2 as a means to supply hydrogen. Unexpectedly, it is not widely known that fuel cells produce CO_2 emissions as much as fossil fuel combustion systems.

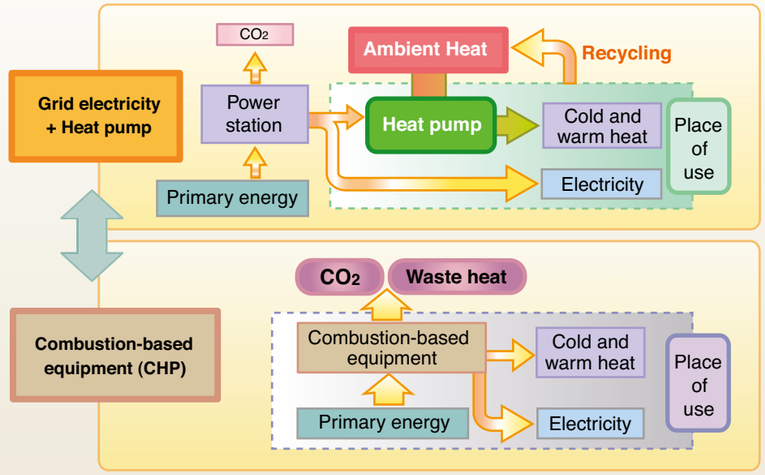
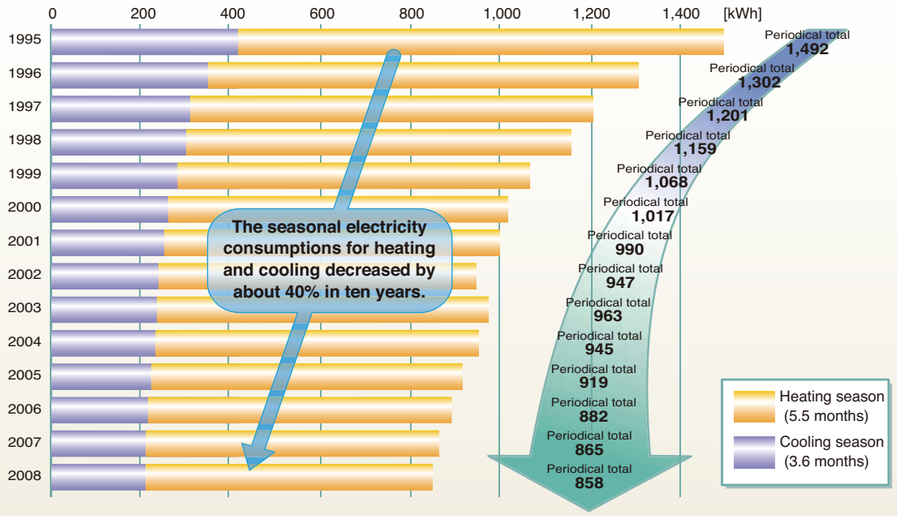


Figure 1.2 Clean and Efficient "Ambient Heat Utilizing Heat Pumps"

Unlike these technologies that may be promising in the future but can hardly yield the effect of CO_2 reduction immediately as of this point in time, the heat pump technology already has a long history of practical utilization. Moreover, more efficient new models of heat pumps can be available in the market and installed at competitive and realistic prices. Heat pumps have an advantage of allowing every one to immediately have the effect of CO_2 reductions, representing a promising measure against global warming.

Such advantage can be explained by pointing out that it is actually available by referring to heat pump air-conditioners in Japan as an example. Today, heat-pump air-conditioners are found in 90% of Japanese households as commonplace home cooling and heating equipment. If anyone says that such heat pump air-conditioners are "actually a device that has a great effect of preventing global warming," you may not readily believe it.

However, the efficiency of air-conditioners (= less consumption of electricity) has dramatically improved since the Top Runner Regulations were applied in Japan since 1999 under the revised Law Concerning the Rational Use of Energy generally known as the Energy Conservation Law.

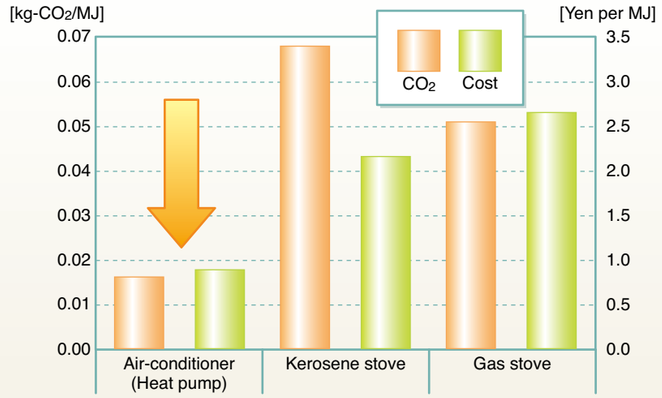


* Simple average values of the seasonal electricity consumption by typical energy-saving wall-mounted models of cooling power of 2.8 kW for both heating and cooling.
* The seasonal electricity consumptions are based on the Japan Refrigeration and Air-Conditioning Industry Association's Standard JRA4046.Source : The Japan Refrigeration and Air-Conditioning Industry Association

Changes in Annual Consumption of Electric Power by Heat-Pump Air-Conditioners of Japan

The efficiency of conventional air-conditioners before the Top Runner Regulations stood at about COP=3. As of 2006, the efficiency of air-conditioners exceeded COP=6(COP represents energy consumption efficiency.The ratio of cooling or heating output divided by the energy inputted.COP=6 means that input of 1 is required to produce heat of 6.) across the board, and air-conditioners that have efficiency close to COP=7 have made their debut. In about only ten years, the energy utilization efficiency expressed by COP has increased by twice as high. This means that the same amount of heat can be produced by a half of the amount of electricity consumed by conventional air-conditioners. In other words, all of the input energy, CO_2 emissions and running cost have been reduced by half.

This efficiency improvement with specific values is summarized below. Comparison was made on how much CO_2 is emitted and how much running cost is required by a heat-pump air-conditioner and combustion-based equipment (gas fan heater and kerosene stove), respectively, to produce a high temperature of 1MJ at the time of heating (Figure 1.4). As a result, it is found that the most efficient air-conditioner with efficiency of COP=6.6 as of 2006 emits half or one-third of the amount of CO_2 emitted by combustion-based equipment and also requires half or one-third of the cost required by combustion-based equipment. (Note: The CO_2 emission factor of electricity and prices of each type of energy are those in the Tokyo district as of 2006.)



<Conditions of calculations>
1.CO_2 emission intensity: electricity 0.37 kg-CO_2 per kWh (results of Tokyo Electric Power Co. in fiscal 2005), city gas and kerosene (the Enforcement Ordinance of the Law Concerning the Promotion of Measures to Cope with Global Warming of Japan)
2.Electricity rate: Tokyo Electric Power Co.'s 2nd block rate unit price in the "Meter-rate Lighting B" category (as of November 2006)
3.Gas charge: Tokyo area of Tokyo Gas Co.'s Tariff B in the "General Contract" category (Applied from October through December 2006)
4.Kerosene price: the Oil Information Center's Petroleum Products Market Data "Kerosene (Sticker Price)" (as of November 2006)
5.Efficiency of equipment: efficiency of heating by air-conditioner is set at COP6.6, and efficiency of heating by gas stove and kerosene stove is 1.0.

Figure 1.4 Comparison of CO_2 Emissions and Running Costs of Heating Equipments of Japan (Per MJ)

However, despite such actual conditions of high efficiency, heat-pump air-conditioners are not necessarily utilized for heating in Japan. Probably because of a still strong preconception that "air-conditioners consume a lot of electricity and are inefficient," air-conditioners for heating and cooling are not used in winter despite the high ownership rate of air-conditioners, and nearly 90% of the heating energy for household use is now still produced by inefficient combustion-based equipment in reality. Rather, CO_2 emissions of heating appliances can be drastically reduced by correct understanding about the realities of such equipment, correct selection of equipment at the time of buying, and utilization of air-conditioners for heating.

This is not necessarily confined to heating. Nearly 100% of the energy used in hot water supply is produced by combustion of fossil fuels. However, the fact that the development of CO_2 refrigerant Heat Pump water heater(Eco Cute) has made it possible to apply heat pumps to hot water supply means that hot water supply is now added to the fields where measures for drastic energy conservation and drastic reduction in CO_2 emissions can be taken. As is the case with heating, the heat efficiency of fossil-fuel-based combustion boilers is about 80%. Even the efficiency of the recently developed high-efficiency water heater that recovers latent heat of steam from exhaust gas is 95%, whereas the COP of Eco Cute as a heat-pump water heater is 4.9 as of 2006. Even if the power generation efficiency of the electricity to drive a heat pump (about 40% in Japan) is taken into consideration, heat energy in excess of the energy inputted by a power station can be produced by a water heater of COP=3 or higher (40% x COP3 = 120%). For these reasons, one unit of Eco Cute (COP=4) is estimated to reduce 0.8 tons of CO_2 a year or produce 65% less CO_2 than conventional water heaters.

Moreover, Eco Cute has an effect of cooling the atmosphere as it pumps up the heat in the air when it boils water. If Eco Cute is installed in all households in Tokyo, Eco Cute is estimated to have an effect of lowering the average atmospheric temperature at dawn in Tokyo by 0.5℃, representing the possibility of measures against the heat island phenomenon problem.

Just as outlined above, heat pumps make a great contribution to the reduction in environmental loads in individual homes, buildings and on a district level. The result of accumulation of such reduction in environmental loads is the "potential of reducing CO_2 emissions by 130 million tons in Japan as a whole" as mentioned later. The aforesaid potential of reducing CO_2 emissions by 130 million tons is not a pipe dream at all. It is a feasible target dependent on the degree of proliferation of the equipment that has already been commercialized and can be introduced.

This effect of prevention of global warming is not necessarily confined to Japan. It can be addressed internationally. There is already an example of a CDM project to introduce heat pumps to renew and replace inefficient heat sources in developing countries. According to the estimation of IEA Heat Pump Center, if the ownership rate of heat pumps reaches 30% in the world at large, its effect is estimated to reduce CO_2 emissions by 1.2 billion tons that account for 6% of the world's total CO_2 emissions.

As mentioned above, various processes to produce heat by burning conventional fossil fuels are expected to yield a large effect of reducing environmental loads through a drastic reduction in CO_2 emissions and exhaust heat on the user side by utilizing the "ambient heat" with various heat-pump appliances.

Energy Security with Heat Pump

Even compared with the food self-sufficiency rate of 40% (on a calorie basis), Japan's energy self-sufficiency rate is by far as low as only 4%. Almost all energy needed by Japan depends on imports from overseas. Its energy basis is very weak. Nevertheless, Japanese people has rarely been aware of such a low energy self-sufficiency rate until recently as an abundance of inexpensive energy has continued to be available amid waning memory of the oil crises that took place more than 30 years ago. However, as a result of changes in the environment of international politics and international energy market, it has begun to be understood with reality that the weak energy basis imposes a large economic burden on the national economy, once the international energy supply and demand has become tight and the prices of various types of energy as the goods traded in the market has started rapidly rising.

For these reasons, amid the changes in international supply and demand situation, each country must take various measures from a security point of view to stably ensure the energy it needs in the future in terms of both quantity and price. In the context of such security, considerations should be given to what roles can be played by heat pumps.

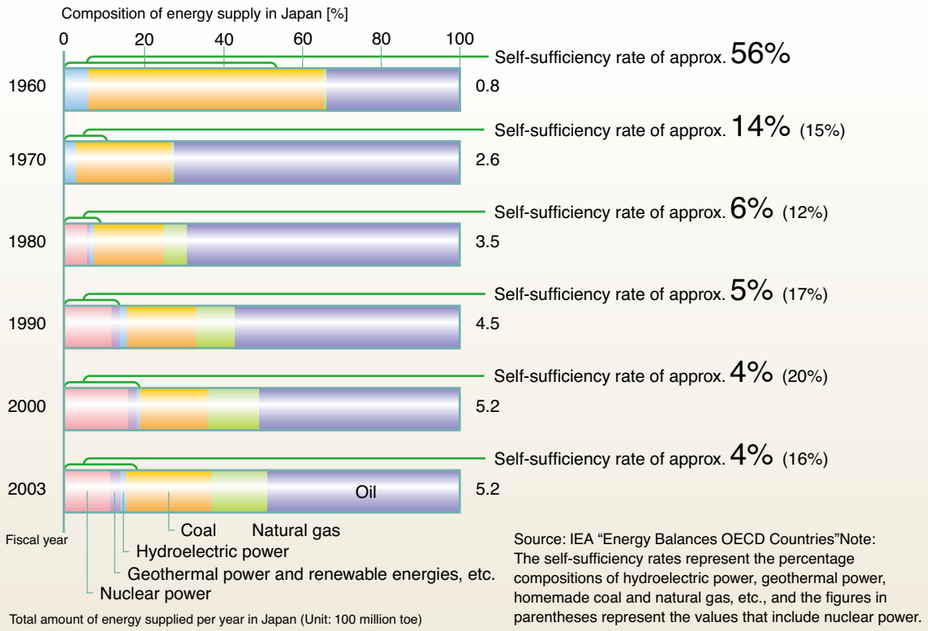


Figure 1.5 Energy Self-Sufficiency Rate of Japan

The basics of the ensuring of security are not to cause a contingency of disruption of energy supplies. To minimize and decentralize such risk, it is possible to take various measures such as "not to depend on specific energy sources," "not to depend on specific countries for energy imports," "to participate in development and reinforce relations with producing countries to obtain the rights for stable procurement," "to select stable energy sources with little risk of disruption of supplies," "to stockpile energy to avoid impact of short-term risk," "to develop domestic energy such as renewable energy to increase the self-sufficiency rate," "to promote international energy conservation led by technology to ease supply and demand," etc.

The "New National Energy Strategy of Japan" that was formulated in 2006 declared "Establishment of Energy Security," "Integrated Solution of Energy and Environmental Issues," and "Contribution to Conquest of Energy Issues in Asia and in the World" as the strategic targets to be achieved, aiming at creating a national strategy that is centered on energy security. As a long-term numerical target for this purpose, the strategy declared an aggressive energy conservation target at the outset of various activities to increase the energy use efficiency rate (per GDP) by 30% or more from the present level by 2030.

Moreover, this strategy of Japan shows the examples of technologies that are expected to be realized by 2030 to further promote energy conservation. For example, the strategy pointed out the need to develop "hyper-combustion system technology" to reduce as much as possible the combustion that loses values of energy, and proposes that the heat pump technology concerning, for example, high-efficiency hot water supply, high-efficiency air-conditioning, etc. should be put into widespread use as the "technology to create energy-saving type informative life space," and the efficiency of heat pump technology should be further improved.

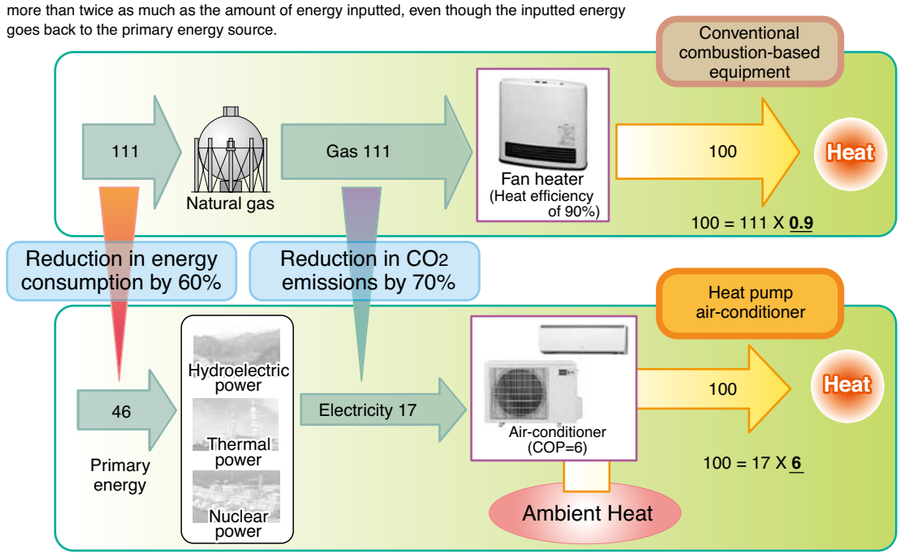
The National Energy Strategy of Japan that is centered on security also has high expectations for widespread use of heat pumps because it is the technology, of which the widespread use yields the social effect that can also yield the effect of reducing CO_2 emissions as described in the preceding section, and at the same time achieves a drastic reduction in consumption of fossil fuels, solving both environmental and energy security issues at the same time.

Conventional combustion-based equipment directly burns fossil fuels such as petroleum, gas and coal to produce necessary "heat" for heating and cooling and hot water supply, whereas highly efficient heat pumps input electric energy that is only a fraction of fossil fuels needed by combustion-based equipment to produce the same amount of heat. Even if the loss at the time of power generation, etc. should be taken into consideration, electrically operated heat pumps require less consumption of primary energy than combustion-based equipment to produce heat. Moreover, the consumption of fossil fuels to operate heat pumps is far less than combustion-based equipment as non-fossil fuel power sources such as hydroelectric power, nuclear power and natural energy account for about half of the electric power to operate heat pumps, though it may vary with the power source portfolio of respective electric power companies. This means that the "ambient heat" used by heat pumps replaces heat of combustion of fossil fuels.

The potential of reducing CO_2 emissions in the commercial sector's air-conditioning and hot water supply fields through the widespread use of heat pumps in Japan is estimated to reach about 100 million tons, but the heat demand covered by the calculation of this potential, which is now produced by direct combustion of fossil fuels, is equivalent to 45 million kiloliters of crude oil. This figure accounts for about 20% of the amount of crude oil imported per year by Japan or 60% of the amount of LNG similarly imported. It is no exaggeration to say that the replacement of such a huge amount of heat demand with supplies by heat pumps that use the "heat in the air" as a major energy source is the same as that Japan as a resource-less country develops purely homemade large oilfields and large gas fields where Japan can freely mine resources.

It is not only confined to the effect of development of purely homemade resources. If the heat utilization in the commercial sector's air-conditioning and hot water supply fields is changed from the present direct combustion of fossil fuels to the electric power used by heat pumps, of which the COP is several times as high, the total amount of final energy consumption in the commercial sector decreases by about 40%. The division of this energy conservation effect with Japan's overall energy consumption represents an energy conservation rate of about 10%. It should be of note that the widespread use of heat pumps in the commercial sector alone can make such a large contribution, compared with the 30% energy conservation target declared in the national energy strategy.

With the combustion-based equipment (in the upper diagram), it is impossible to utilize the amount of heat in excess of the amount of energy inputted. With the high-efficiency heat pump that uses heat in the air (in the lower diagram), it is possible to utilize the amount of heat that is more than twice as much as the amount of energy inputted, even though the inputted energy goes back to the primary energy source.



Note: As for the CO_2 intensity, the values of Tokyo Electric Power Co. are applied.

Figure 1.6 Use of Ambient Heat by Heat Pumps Is the Key to Energy Conservation and Reduction in CO_2 Emissions

The effect of widespread use of heat pumps is expected to also foster changes in energy supply structures. When heating and hot water supply are provided by heat pumps, though the electric power demand increases, there is no effect on the formation of peak in summer, contributing to the improvement of availability factors of electric power equipment through the leveling of electric power load curve. A 1% improvement of electric power load factor in Japan is said to have an effect of reducing the electricity supply cost by about 1%, and the benefit of which is widely enjoyed by society at large. It is generally understood that the use of electricity for cooling is a cause of increasing peak power demand in summer. But the renewal and replacement of conventional cooling equipment with high-efficiency and low-power-consumption latest equipment has an effect of contributing to power peak cut. It is also possible to easily avoid accumulation of peak in summer and promote load leveling by combination with thermal storage equipment to meet new cooling demand such as shift from other heat sources.

Like this, the load leveling of electric power, particularly the creation of loads during the time zone of midnight light loads contributes to an increase in the supply capability of nuclear power generation that conducts output-constant operation as a base supply capability.

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.

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CO_2 Reduction by Heat Pumps