THE EFFECT AND POTENTIAL OF HEAT PUMP TECHNOLOGY

Takashi Yatabe
Business Coordination Dept.
Heat Pump & Thermal Storage Technology Center of Japan

Abstract: Problems associated with global warming and energy supply are the issues that humankind century must overcome. Consumption of fossil fuels by consumers is affected by a steep rise in its prices, and that the reducing CO_2 emissions as a greenhouse gas (GHGs) are solely dependent on the efforts of consumers who would not take radical measures. The key to resolving these problems lies in realizing "dramatic improvements in energy utilization efficiency" and "a transition to post-carbon energies." A technology that can accomplish them compatibly is "heat pump". Heat-pump heaters that utilize ground-source heat have already been available in Europe and North America. In Japan, water heaters that utilizing air-source heat are commercialized and one million units have already been introduced in the market. For heating and water heating, however, heat generated by combustion of fossil fuels is used in general, and it is hard to say that heat pumps have come into wide use as yet. Now, it's time to promote wide use of heat pumps through international cooperation hand in hand, so as to solve global warming issues.

Key Words: ***heat pumps, CO_2 reduction potential, renewable energy, low-carbon society, ambient heat,***

1 INTRODUCTION

Concerns over resource and energy issues have been rapidly spreading all over the world. At the G8 Summit held in June 2007 in Heiligendamm, Germany, the world's energy security was one of the major topics for discussion. The steep rise in crude oil prices serves as a backdrop. The crude oil price per barrel exceeded 100 dollars (as of January 2008), and has doubled only in two years. In addition to the political instability in the Middle East, moreover, the rapidly growing energy demand in developing countries is pressing crude oil price to further rise. In European and North American countries, as a result, the move to seek inexpensive and stable energy, which is not influenced by the unstable of international relations is now accelerated.

Another reason for growing concern over energy issues is the challenge how to handle global warming. The Kyoto Protocol, which was resolved at the 3rd Conference of the Parties to United Nations Framework Convention on Climate Change (COP3) in 1997, came into effect in February 2006. To achieve the target of CO_2 emissions reduction prescribed by the protocol, it is necessary to reduce the consumption of fossil fuels substantially.

There are some choices of alternative energy to reduce CO_2 emissions. On the supply side, they can choose wind power, hydroelectric power, photovoltaic power, biomass, nuclear power, and others. In addition to technological innovations in terms of costs and techniques, it is necessary to combine these types of alternatives that does not depend largely on fossil fuels. In other words, the ratio of non-fossil energy in the power source portfolio should be increased on the supply side.

However, what should be noted is that CO_2 emissions reduction and energy security do not lie in the supply side only because measures taken in the demand side are also important. Unless measures for demand and supply are closely connected with each other, highly practical effects cannot be yielded.

Looking closely the demand for energy, particularly in the commercial sector, large proportion is occupied by the heat utilization such as cooling, heating and hot water supply. Even in developed countries, these heat utilization fields still depend largely on the heat energy generated by combustion of fossil fuels. This brings the result that consumers' direct consumption of fossil fuels is immediately affected by social impact due to a steep rise in fuel prices and disruption of fuel supplies, if the things get worse, they will cause concerns over economic confusion and impaired confidence in the government. One of major solutions to avoid such troubles is to increase secondary energy utilization with high efficiency and renewable energy on the consumer side.

In the heat utilization fields, it is necessary to pay much attention on the utilization of ambient heat existing in the air, ground and river water and seawater. The widely introduction of heat pumps is a realistic means to improve the qualityof ambient heat and to convert it into useful heat energy. However, it is hard to say that heat pumps have come fully into wider use. To surmount this challenge, it is necessary for each country to promote the wider use of heat pumps in a policy-based manner and keep pace with the proactive actions of international community.

2 Current Situation

Based on a concept devised by Sadi Carnot and developed by Lord Kelvin and others in the 1800s Europe, this thermal utilization technology has a long history for use in refrigerators and for cooling.

In contrast to cutting-edge technologies under development that tend to attract public attention with loud fanfare and drum up expectations, however, the public has shown little interest in the fundamental mechanism of heat pump, which is a mature conventional technology. For all these reasons, the truth about heat pumps – that widespread dissemination of the heat pump technology holds a huge and realistic potential for resolving both energy and environment issues confronting humans – has not been fully understood in spite of its monumental significance.

3 Need for Combustion-free Systems: A Transition from Fossil Fuel-dependent Culture

In the commercial sector that includes residences and office buildings, the bulk of the energy has been consumed for heating, hot water supply and other purposes to sustain living. This energy comes primarily from "combustion" systems that utilize thermal energy generated by burning fossil fuels.

The 4th Assessment Report of the United Nations Intergovernmental Panel on Climate Change (IPCC) has concluded that global warming, which today calls for urgent response, is "very likely" to have been caused by an increase in the atmospheric concentration of carbon dioxide (CO_2) that accompanies mass consumption of fossil fuels as a result of human activity.

In order to resolve global warming issues, break away from the constraints posed by fossil energy resources and realize environmental preservation along with sustainable

development of our economy and society, we will need to build a “low-carbon society” that accomplishes a substantial reduction of CO_2 and other GHG emissions and stabilization of the atmospheric concentration of GHGs at levels that would not adversely impact the climate.

In this regard, heat pump is the key technology that would enable energy suppliers and consumers to make a voluntary choice to join the action to halt global warming towards this goal.

4 Outstanding Features of Heat Pump: A Highly Efficient Heat Transport Engine

Heat pumps have two outstanding features.

First, a heat pump moves thermal energy between out-of-doors and indoors instead of “generating” thermal energy from scratch by combustion. The heat pump, based on a simple heat transport engine that applies basic principles of thermodynamics, is already widely used in refrigerators and for cooling and other purposes.

Second, theoretically speaking, the energy consumption efficiency of a heat pump system is higher than that of a combustion-based system by several times to more than tenfold. The amount of thermal energy transported is much larger than the inputted energy (normally electric power) consumed to power thermal transport. This means that collecting ambient heat by a heat pump after converting fossil fuels into electricity is a more efficient – resource-saving and CO_2 reducing -- means of obtaining “heat” than burning fossil fuels directly.

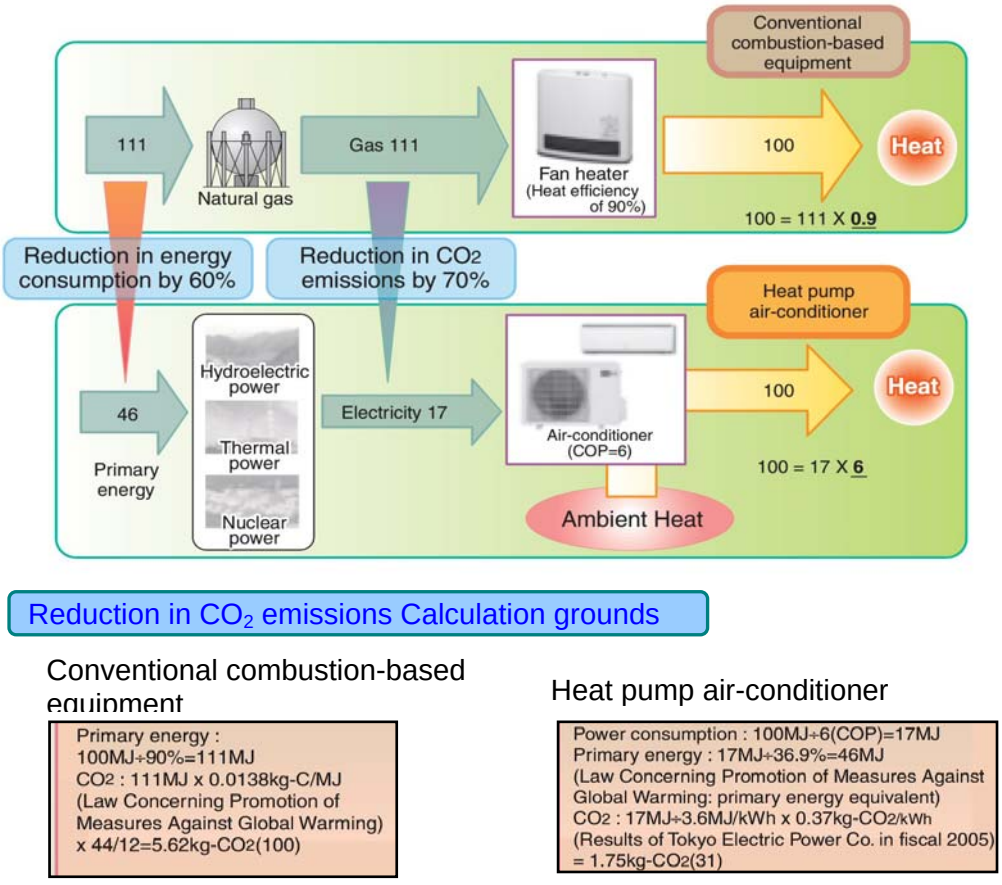

Figure 1: Use of ambient heat by heat pumps is the key to energy conservation and reduction in CO_2 emissions

In the past, attention on the heat pump, being an essential technology for cooling purposes, has been focused primarily on the first feature as a heat transport engine. Although its theoretically high efficiency had been known, little attention has been paid to the energy-saving properties, the second feature, of this technology partly because the technology was in the developing stage and also because fossil fuels for competing combustion equipment could be obtained at low cost.

However, amid major transformations in energy, environment and other social conditions in the past decade or so, the appearance of many heat pump equipments with high energy consumption efficiency on the market has reinvigorated interest in the energy-saving properties of heat pumps.

5 Rapid Technological Progress

As a resource-scarce nation, Japan has waged a government-orchestrated campaign to promote energy efficiency, drawing lessons from the Oil Crisis in the 1970s that triggered the disruption of resource imports. These efforts helped the nation to achieve one of the highest energy conservation standards in the world.

Most households in Japan are equipped with heat pump-based heating and cooling equipment. Under the government's Top Runner Regulations, a unique program even by global standards, home appliance retailers dispense at reasonable prices air-conditioners that vie for the world's highest level performance. Highly efficient heat pumps are employed in large-scale district heating and cooling (DHC) services. Moreover, Japan developed, for the first time in the world, a CO_2 refrigerant heat pump water heater, an equipment that takes advantage of "heat in the air" to supply hot water. Moreover, one million units of CO_2 refrigerant heat pump water heaters that boil water with "air-source heat" have come into wider use.

Rapid technological innovation in the heat pump technology has been fueled by two major factors: continuous improvement or "kaizen" at the production site toward even greater leaps in energy conservation and expectations for a "combustion-free technology" that would help combat global warming.

A monumental breakthrough was achieved with Eco Cute, a CO_2 refrigerant heat pump water heater, which was developed in 2001 in Japan as the first such product in the world. Eco Cute opened up new possibilities for the application of heat pump in hot water supply systems, an accomplishment that had been difficult with CFC-based refrigerants, while its high efficiency led to substantial improvements in both energy conservation and CO_2 reductions.

The Japanese government has introduced a scheme named the Top Runner Program in an effort to encourage continuous improvement in the energy-saving performance of various home electric appliances. This one-of-a-kind program in the world has served to double the energy consumption efficiency of air-conditioners for residential use in just ten years and consolidated the status of heat pumps as being far superior to combustion-type heaters in terms of energy-saving and CO_2-reducing performance.

As of 2008, 4.5 kW Eco Cute is rated at COP4.9 in ambient temperature at 16℃/12℃ (DB/WB), water temperature at 17℃, and boiling temperature at 65℃ (annual COP is about 3 or higher), and 2.2 kW residential heat pump air conditioner of the annual COP (Japanese standard called APF, or annual performance factor) is in excess of 6.6.

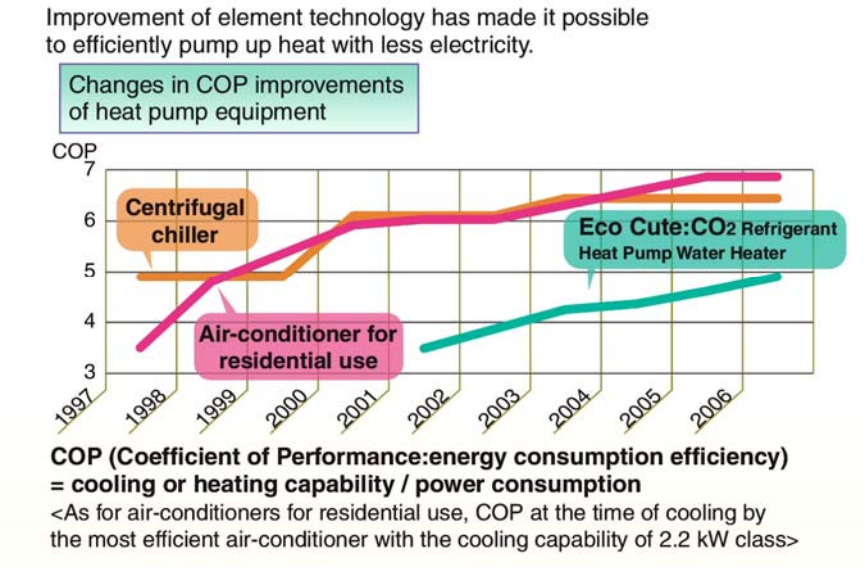

Figure 2: Heat pumps of Japan are remarkably increasing their efficiency in recent years

Globally, high-efficiency centrifugal refrigerators, developed in the U.S. with the application of heat pump technology, are widely used for cooling office buildings and district cooling (COP is 6.0 or higher). Also, in recent years, further advances in the energy conservation performance have been achieved with the commercialization of centrifugal refrigerators that allow variable speed operation with inverter control (COP is 20.0 or higher at the time of partial load).

In Europe, systems that employ heat pumps to utilize heat in the underground for heating have become more popular. Underground heat-based heating can only be realized with the application of heat pump technology.

These numerical values are mentioned in the Section of Measures in IPCC's 4th Report, and the usefulness of heat pumps is scientifically proven.

Furthermore, in Japan, heat pumps are now being used in clothes dryers, signifying a new stage in their applications.

6 Potential of CO_2 Reduction

Controlling CO_2 emissions has been a major motivating force behind the recent surge in the development of numerous heat pump systems in Japan.

In a nation with rapidly expanding energy consumption, heating and hot water supply account for nearly half of the energy consumed in the commercial sector for residential and business uses, which is one of the main contributors to the CO_2 increase. Moreover, about 90% of hot water supply, heating and other heat-based demands are met by the heat generated by burning CO_2-emitting fossil fuels. It is against this background that heat pumps are drawing huge attention as an alternative, CO_2-reducing technology for fulfilling heat-related demands.

By replacing fossil fuel-based direct combustion systems prevalent today with heat pump equipment, which drastically improve energy utilization efficiency with the use of “heat in the air,” to meet such demands for cooling and heating, primary energy consumption and CO_2 emissions can be reduced substantially without changing the amount of thermal energy available to users.

A trial calculation was made on the basis of current energy demand figures in Japan to gauge the impact of the maximum possible introduction of heat pumps on CO_2 emission reductions. Thanks to extraordinary progress in the heat pump technology that led to drastic improvements in energy utilization efficiency in recent years and an expansion in the scope of application, the projected CO_2 emission reductions totaled 130 million tons per year, equivalent to about 10% of Japan’s total emissions at present.

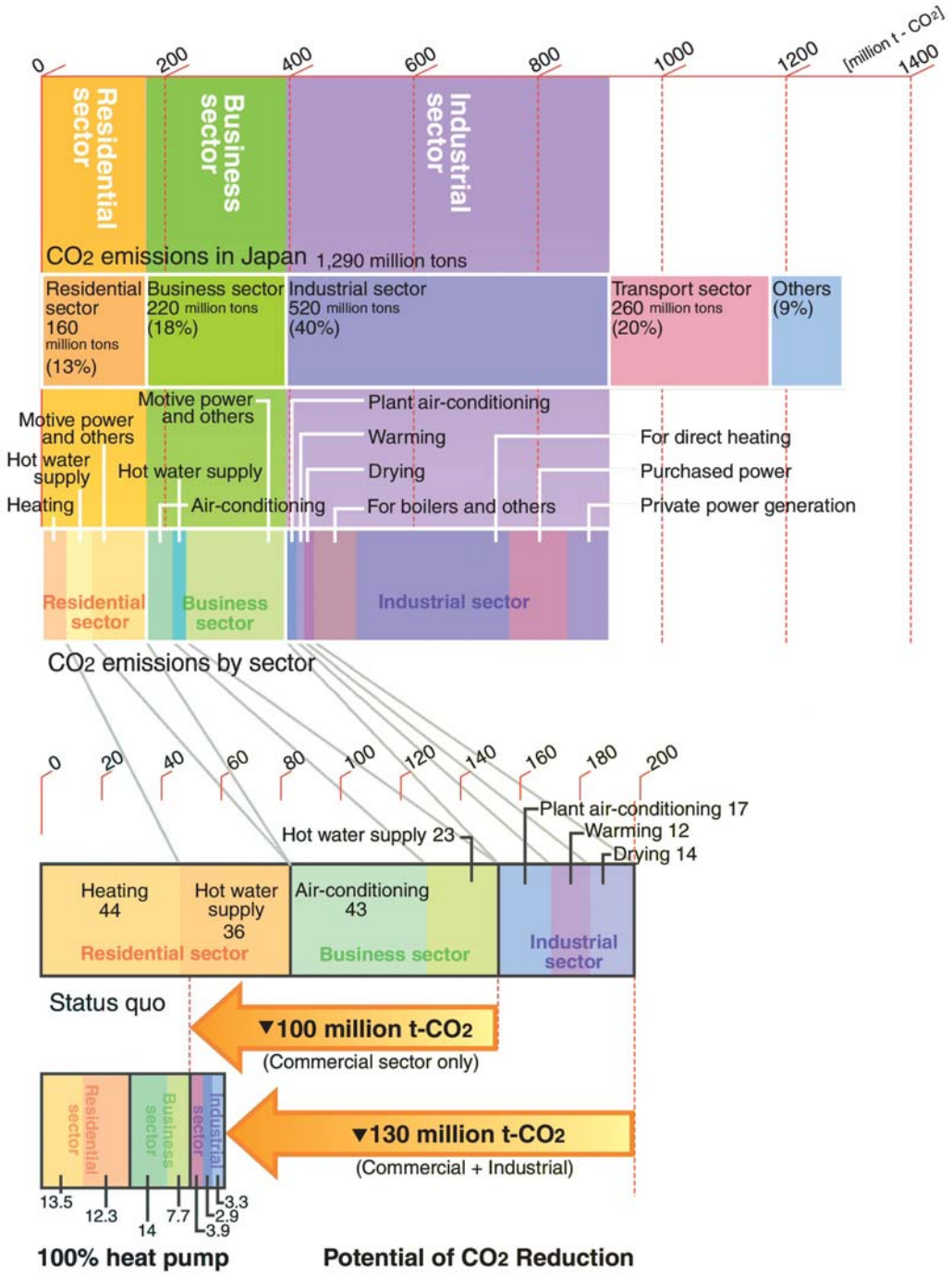

Figure 3: Potential of reduction CO_2 emissions by heat pumps in Japan

Among others, CO_2 emissions are expected to be reduced by 54 million t-CO_2 per year in the residential sector. This means that CO_2 emissions from households can be reduced by about 40%. Compared with other sectors, the effect of CO_2 emissions reduction is higher in the residential sector. The same calculation results also apply to the residential sector of G7 countries.

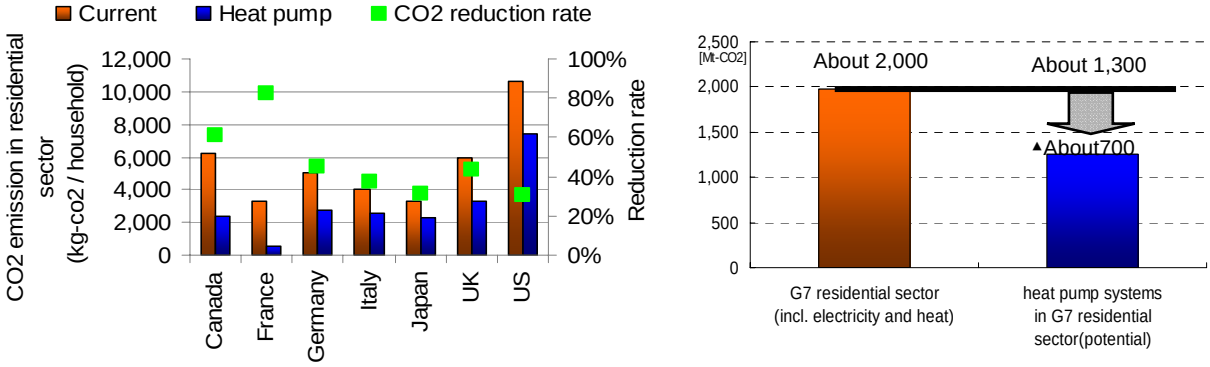

Figure 4: CO_2 reduction potential in G7 residential sector

On the other hand, IEA Heat Pump Center has also calculated the potential of the world's CO_2 emissions reduction by the widespread use of heat pump equipment on a trial basis. CO_2 emissions can be reduced by 650-2,000 million t-CO_2 in the residential sector, and about 6-12% or 1.2-3.7 billion t-CO_2 in the business and industrial sectors, according to the trial calculation.

Furthermore, this advantage of CO_2 reduction can be realized by heat pump equipment that are already available on the commercial market, instead of having to place expectations on the development of unreliable future technology or equipment. In other words, we should draw much attention to this highly effective and realistic measure because the advantage of significant CO_2 reductions can be obtained immediately by anyone, anywhere, anytime who would care to purchase and install a heat pump-based unit.

7 Significance of Dissemination that Extends beyond CO_2 Reduction

Heat pumps are now expected to solve both energy and environmental issues at the same time in Japan. This is because the evaluation of heat pumps is now established as realistic and highly effective technology to save energy and reduce CO_2 emissions. We consider them as the measures to combat global warming have become more urgent and radical in recent years.

With the intensification of measures to tackle global warming in recent years, the reputation of the heat pump technology has come to be established as a realistic and highly effective means for energy conservation and CO_2 reduction. This, in turn, further raised expectations on heat pumps as a tool for resolving both energy and environmental problems at the same time.

Also, the successful development of various types of heat pumps in Japan may be attributed to its climatic conditions – warmer and more humid than in Europe or the U.S. – that are fit for heat pumps. By installing a heat pump air-conditioner, heating and cooling needs can be met without having to install separate units, which means small energy consumption and less energy costs. The same applies to heat pump hot water supply.

However, due to their high initial costs in comparison to simple combustion-based systems, the dissemination of heat pump systems has been far from adequate.

On the other hand, China, India and Brazil whose climates are much milder then those of Japan, Europe and North America, are rapidly growing in economy,. These emerging countries are becoming richer with economic growth, and more and more buildings and houses are constructed. As a result, the energy consumption in the commercial sector is expected to increase, and push up further the demand for cooling. Though all cooling units are heat pumps, it is desirable to induce the introduction of high COP heat pumps from the outset in a policy-based manner. If such efforts are neglected, the peak demand for electricity will rapidly increase, and, as a result, they cannot help but construct more power stations to meet the increased demand. A huge amount of funds is required to construct additional power stations, and consequently the availability factors (load factors) of power generation and power transmission equipment may decline, causing a serious impact on energy security both at home and abroad as well as on electricity rates.

In an effort for doing without oil and without global warning, steps to promote the use of heat pumps are actively pursued in Europe and the U.S. with a view to promoting the thermal utilization of renewable energy and also mitigating the energy supply-demand situation that has tightened further in response to the growth in global energy demand that is expected to continue into the future.

EU announced a draft of its new Directive on renewable energy in January 2008. In this draft, it is proposed that ground-source and air-source heat pumps that meet the efficiency standards of the eco-labeling should be treated as heat utilization of renewable energy.

As we have seen, the replacement of fossil fuel consumption with the “heat in the air” amassed by heat pumps carries great significance in various ways. Its CO_2 reduction performance would not only have a huge impact on controlling global warming, but also significantly cut back on the amount of resource imports and contribute to energy security, and promote the utilization of renewable energy that takes advantage of heat in the air that relies on a clean and unlimited supply that exists in abundance in the natural world.

Lastly, I would like to introduce some examples of efforts to promote the wider use of heat pumps.

The Germany government announced a bill to promote renewable energy in the heat field, and presented to the world its idea to promote, in a policy-based manner, the wider use of both ground-source and air-source heat pumps, of which the annual COP (Jahresarbeitszahl) is higher than a certain level.

The Energy Agency of Sweden has proposed standardization of international statistic on heat energy generated by heat pumps.

The Japanese government is launching a collaborative public-private sector campaign to promote the use of heat pump units, rating them highly in the Kyoto Protocol Target Achievement Plan, New National Energy Strategy, reports by environment and energy-related government councils and other programs. Also, the government hopes to make a positive contribution by disseminating Japan’s energy conservation technology, which ranks among the top in the world, toward building a “low-carbon society” for a better global environment.

The Council for Science and Technology Policy of Japan explained that it is important to allow both environmental protection and economic growth, therefore promoting the wider use of heat pump technology all over the world is necessary to seek them compatibly. “Cool Earth--Energy Innovative Technology Plan” (Ministry of Economy, Trade and Industry), which

defines heat pumps as the core technology for measures to be taken in the commercial sector, is declared to the world.

Figure 5: Prime Minister Fukuda who watches a heat pump unit in Council for Science and Technology Policy 73rd session

In this way, we would like to expect a well-balanced policy mixture to promote the efforts that yield the same effects to spread out to many other countries.

I would like to mention ten themes of merits of such heat pumps.

Viewpoint of Environmental Protection	#1	It is highly worthwhile for the world at large to make efforts for promotion of widespread use of heat pump technology as a "technology to cope with global warming."
	#2	Ambient heats, such as heat in the air or heat in the ground are "renewable energy."
	#3	Reduction in artificial waste heat and recycling of heat ease "heat island" phenomena.
Viewpoint of Energy Security	#4	Replacement of fossil fuels with ambient heat improves "energy security."
	#5	A realistic tool to "de-carbonization" on the demand side.
	#6	Widespread use of thermal storage systems promotes "load leveling" of energy.
Viewpoint of Technological Contribution	#7	"International contribution" can be facilitated by using the energy conservation technology
	#8	Promotion of energy conservation technology "invigorates the manufacturing industry."
	#9	Heat pump technology can evolve as an "advanced environmental technology" because it is expected to find other large fields of application in the future.
Overall Viewpoint	#10	"High feasibility" that allows anyone to immediately address practical application of heat pump technology

Figure 6: Heat Pumps Merits 10

8 Conclusion

To date, heat generated by combustion of fossil fuels at places of demand has been used for heating and hot water supply in general, and it is hard to say that heat pumps have come into wide use. Consuming fossil fuels at places of demand means a high risk of consumers to be directly affected by the impact of a steep rise in fossil fuel prices. Moreover, it is feared that distributed small-scale CO_2 emission points may not be regulated because of their small scale, and that such small-scale CO_2 emission points may not be covered by regulatory authorities and the expected effects cannot be yielded. Moreover, the wide use of the technology to capture and store CO_2, which is expected to be developed in the future, could be hindered.

The key to resolving these problems lies in realizing “dramatic improvements in energy utilization efficiency” and “a transition to post-carbon energies.” A technology that can accomplish both these tasks simultaneously is the heat pump.

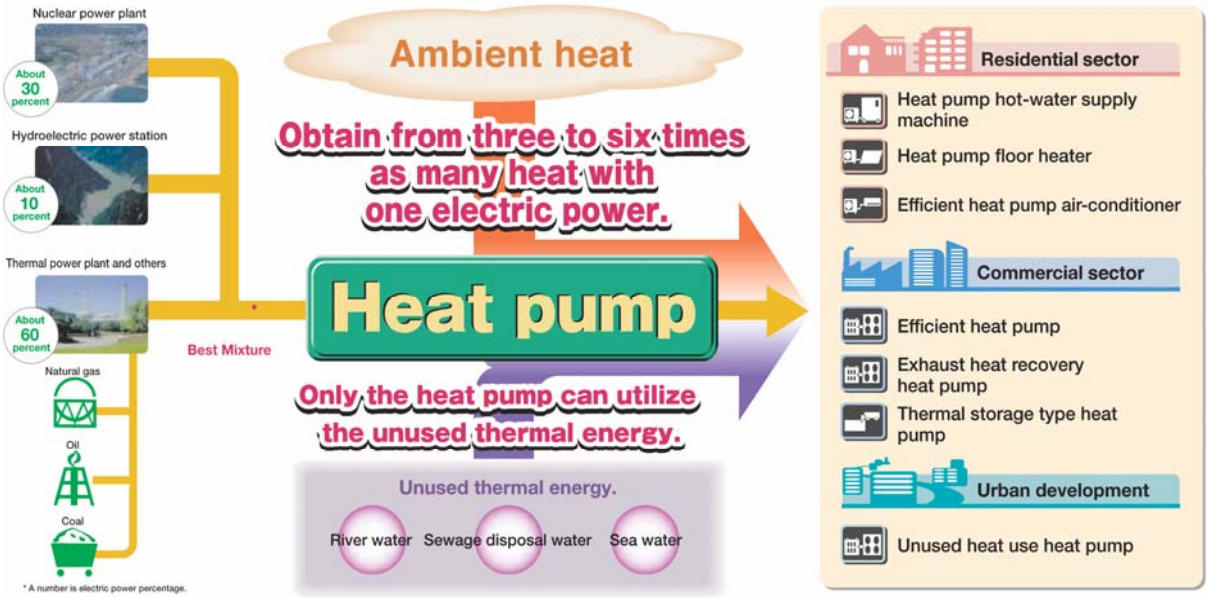

Figure 7: Heat Pumps to Meet Power Supply and Demand and Environmental Measures

Heat pumps – using the power of technology to recycle the “heat” found in the “air” and “underground” – a recyclable, clean and unlimited supply with the blessing of the sun. A solar energy recycling society, which recycles the blessing of the sun – the heat in the air, heat in the underground, heat in the lake water and heat in the river water – is the ultimate sustainable society. The time has come for people in the world to join hands, with each individual citizen and business utilizing the technology and putting the achievements together toward building a sustainable society.

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