POLICY TREND OF HEAT PUMP IN JAPAN

Masanobu SASAKI, Manager, Heat Pump & Thermal Storage Technology Center of Japan, Tokyo, Japan

Abstract: The potential CO_2 reduction from heat pump systems in Japan is estimated to be about 140 million tons. Heat pump technology has been attracting attention as a measure to mitigate global warming because of significant CO_2 reduction effects. This report described the history of improvements in heat pump efficiency, the spread and estimated future CO2 reduction potential, and the possibility of contributing to economic growth. This report also introduced support systems, such as tax incentives and subsidies, and definitions of renewable energies in relation to the trend in the heat pump policy of the Japanese government. In addition, the report estimated the amount of air heat used for residential room heating, residential water heating, and water heating for commercial uses to show that the use of renewable heat can be expanded through the spread of heat pump systems.

Key Words: heat pump, policy, renewable energy

1 INTRODUCTION

The 16th Conference of the Parties of the United Nations Framework Convention on Climate Change (COP16) was held in Cancun, Mexico, at the end of 2010. At this conference, the delegates reached a decision to continue discussions on the reduction of greenhouse gases (GHG) among all member nations toward COP17, which would be held one year from COP16. One of the decisions included the preparation of documents on nationally appropriate mitigation actions (NAMAs) by developing countries. Important aspects of the mitigation of global warming include maximum efforts to reduce energy consumption by industrialized countries and developing countries to construct sustainable societies. In private sectors around the world, cooling, heating, and water heating account for a large portion of energy consumption. Under such circumstances, heat pump technology is expected to deliver significant effects on reducing carbon dioxide (CO_2) in such sectors. In Japan as well, there is a demand for promoting the spread of heat pump technology for energy conservation and CO_2 reduction, and the technology has been steadily spreading. This report describes the policy trends concerning the heat pump in Japan.

2 EFFICIENCY IMPROVEMENT AND THE HISTORY OF THE SPREAD

2.1 Efficiency Improvement

Figure 1 shows the transition of the efficiency of major heat pumps. The competition to achieve higher efficiency due to the effect of the top runner system introduced by the Revised Law Concerning the Rational Use of Energy in April 1999 has improved the average cooling and heating efficiency of household air conditioners (RAC) two-fold for COP6.7 over the past ten years or so. Besides the equipment covered in the top runner system, the centrifugal chillers for commercial and industrial uses have also improved the efficiency by about 40% and achieved COP7.0. In addition, EcoCute, the CO_2 refrigerant heat pump water heating system (HPWH) that was the first commercialized model in Japan and introduced in

2001, also improved the mid-term unit efficiency of a heat source equipment (COP) and achieved COP5.1. Companies have been working to improve annual efficiency in recent years. As a result, the annual performance factor of hot water supply (APF), the performance evaluation method that started in 2007, has been improved to APF3.9. EcoCute is now being considered for inclusion in the top runner system. The Subcommittee on the Judgment Criteria for the Heat Pump Water Heating System in the Energy Conservation Standards Department of the Advisory Committee on Natural Resources and Energy is examining targeted standards in preparation for the report that will be written around June 2011. Heat-pump-style hot water floor heating systems have been spreading in recent years, and high-efficiency models that deliver COP4.4 are now commercially available.

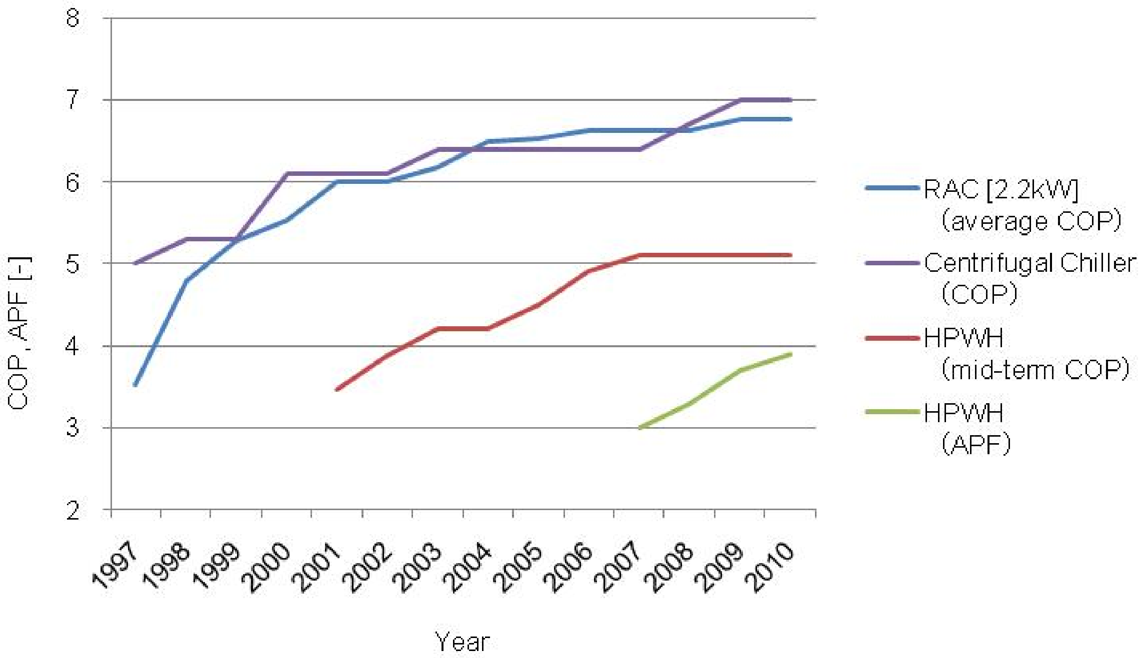

Figure 1: Transition of heat pump efficiency

2.2 History of the Spread

Figure 2 shows the transition of shipment records for major heat pump systems for air conditioning (JRAIA 2010). The number of shipments plunged in 2009 due to the global economic slowdown. Although the trend for shipments of absorption chillers is decreasing, shipments of all equipment are stable.

The heat pump water heating systems with significant CO_2 reduction effects are rapidly spreading due to the increasing awareness of the mitigation of global warming in recent years. Figure 3 shows the changes in the accumulated number of EcoCute units sold for residential use (JRAIA 2010). Sales have rapidly increased, reaching 2.5 million units at the end of September 2010. Now, more than ten domestic manufacturers are participating in the EcoCute market. A wide variety of EcoCute lineups are commercially available: multi-purpose types that can also be used for floor heating, units for housing complexes, devices for rented apartments for single-person households, compact systems suitable for reforms, units for cold regions that work in temperatures of –25°C, and hybrid types combined with the solar heat collecting system. The EcoCute combined with a 4m^2 solar heat collecting system can improve efficiency to APF5.0. Figure 4 shows the transition in the accumulative number of heat pump water heating systems for commercialized uses sold to customers. The heat pump water heating systems are spreading for both residential uses and commercial uses, and sales exceeded 12,000 units at the end of fiscal year 2009.

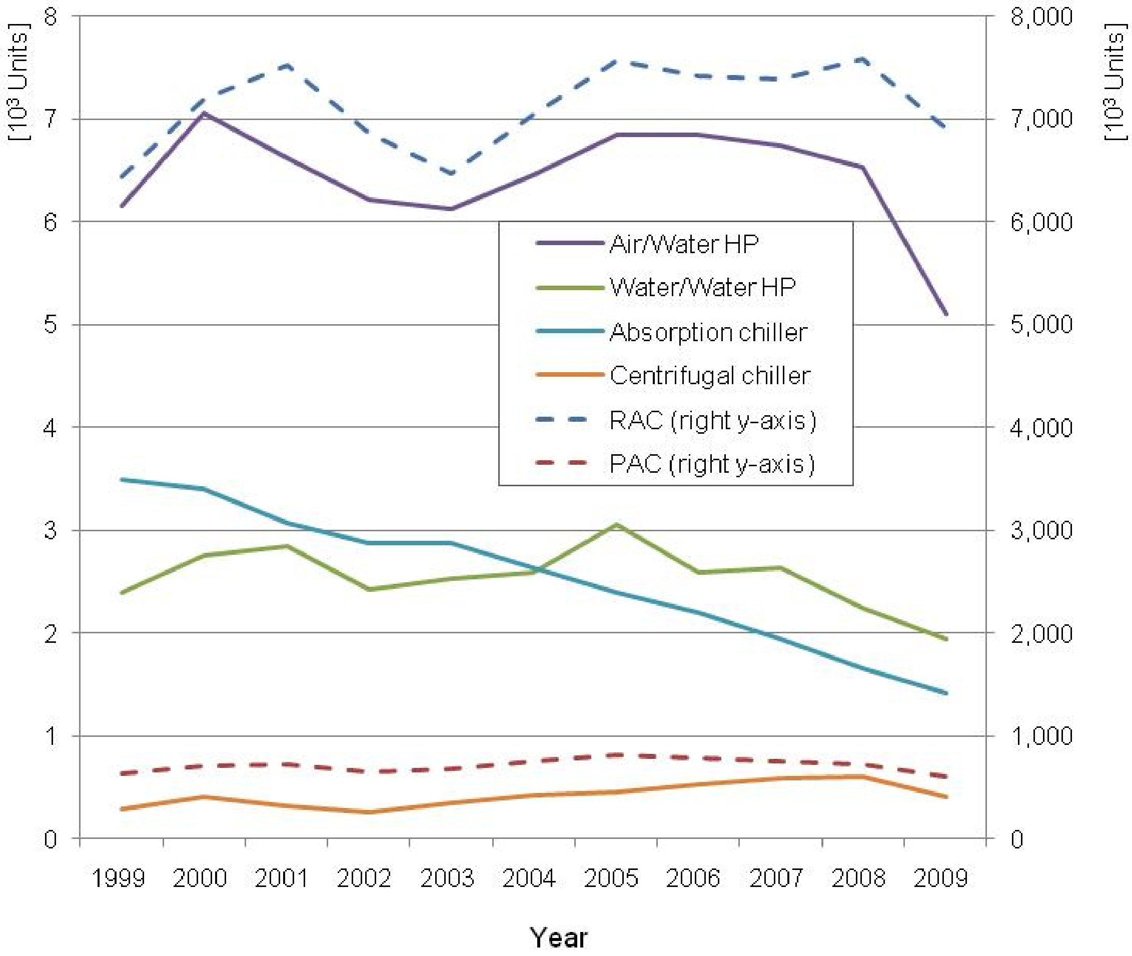

Figure 2: Transition in the shipment of heat pump systems for air conditioners

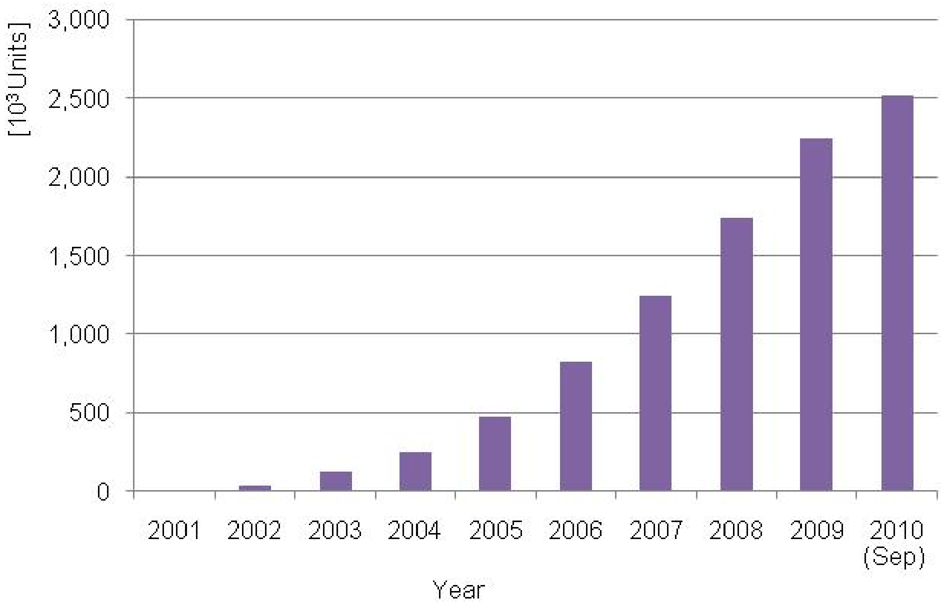

Figure 3: Accumulative number of EcoCute for residential uses

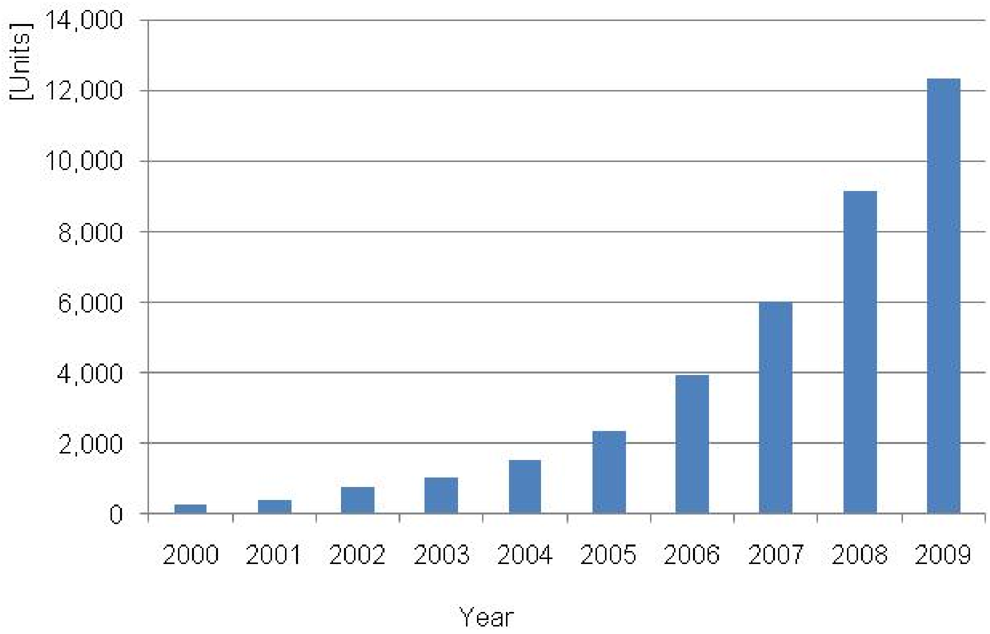

Figure 4: Accumulative number of heat pump water heating systems for commercial uses

3 EFFECTS OF THE SPREAD OF THE HEAT PUMP

3.1 CO_2 Reduction Potentials

Figure 5 shows the energy consumption structure in the residential sector (IEEJ 2010). Water heating consumes the largest amount of energy in households. Combined water heating and room heating, the heating accounts for more than half of energy consumption in the households. Combustion of fossil fuel accounts for a large portion of the breakdown of energy types for these two uses.

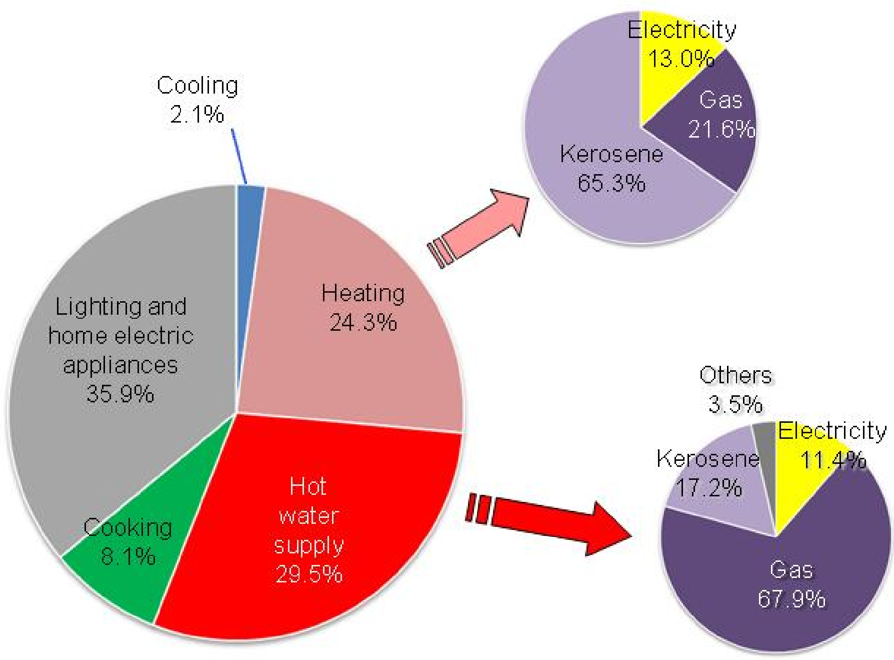

Figure 5: Energy consumption structure in the residential sector

Figure 6 shows the energy consumption structure in the commercial sector (IEEJ 2010). The commercial sector includes offices, restaurants, hospitals, and hotels; thus, there is high demand for water heating and energy consumption. Therefore, air conditioning and water heating account for a large portion of the energy consumption in the commercial sector, and the combustion of fossil fuel also accounts for a large portion of energy consumption.

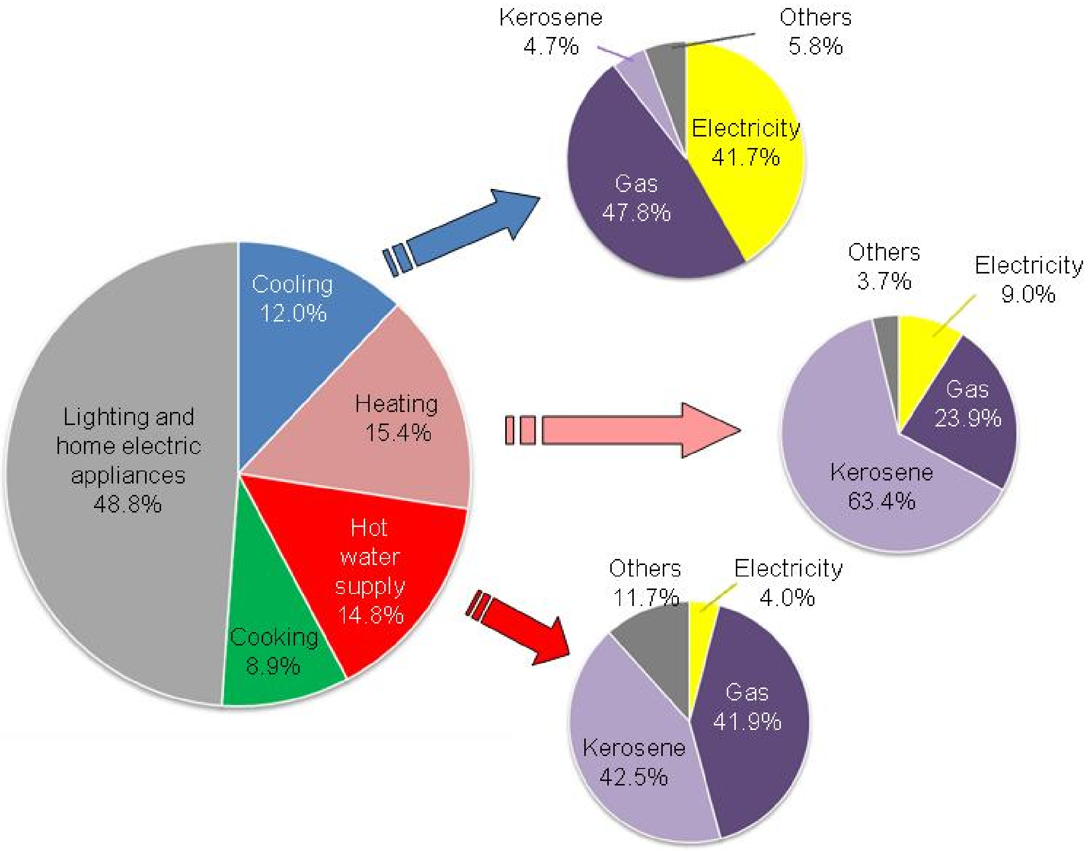

Figure 6: Energy consumption structure in the commercial sector

There is a potential to reduce about 100 million tons of CO_2 if all room and water heating in residential sector, as well as air conditioning and water heating in the commercial sector, were replaced with heat pumps in the future (HPTCJ 2007). Table 1 shows the potential CO_2 reductions in each sector. Besides residential and commercial, CO_2 reduction effects can be expected from air conditioning by industrial boilers, substitution effect of water heating and drying at less than 100°C, and heating in agricultural greenhouses. Moreover, the steam-generating heat pump system, which is now in development, is expected to replace the demand for low-temperature steam heating; thus, it has the potential of reducing about 10 million tons of CO_2 (SGEIHP 2010). The sum of the potential reductions is about 140 million tons, which means a large reduction potential exceeding 10% of the total emissions in Japan.

Table 1: CO_2 reduction potential in each field

		Present emmisions [10^4 t-CO2]	Reduction potential [10^4 t-CO^2]
Residential	Room heating	4,400	3,050
	Water heating	3,600	2,370
Commercial	Air conditioning	4,300	2,900
	Water heating	2,300	1,530
Industrial	Air conditioning by industrial boilers	1,690	1,290
	Water heating for productive process	1,230	940
	Drying (Less than 100℃)	1,410	1,080
	Low-temperature steam heating	1,170	850
Agricultural	Greenhouse heating	35	28
Total		20,135	14,038

3.2 Economic Effects

The spread of heat pump systems is expected to have an effect on the reduction of CO_2 emissions and the economy of Japan. We calculated the economic effects from the introduction of equipment, mostly conversion from the combustion-style heat source systems to high-efficiency heat pump systems, which is associated with significant CO_2 reductions based on the prospect of the spread of heat pump systems in 2020, as follows. About 1,800 billion yen in direct effects (market size) can be expected by 2020 through the new spread of applicable heat pump systems. In addition, about 4,600 billion yen in production inducement effects can be expected from raw materials to manufacture heat pumps. The total economic effect could be as high as about 6,400 billion yen (SGEIHP 2010). Meanwhile, this economic effect is expected to create about 230,000 jobs. When the production inducement factor from heat pump systems not included in the calculation is added to the assumption that it is the same value, the total economic effect (direct effect and production inducement effect) of all heat pump systems is estimated to be about 12,000 million yen by 2020.

4 TREND OF DOMESTIC POLICIES

4.1 Government Policies

The Basic Energy Plan, approved by the cabinet in June 2010, stipulates a 50% reduction in CO_2 emissions from the residential sector as the target for 2030. As ways to realize this goal, the Plan aims to realize net zero energy houses (ZEH) and net zero energy buildings (ZEB) in the new construction of buildings by 2020. The Plan also emphasizes the high CO_2 reduction potential of heat pumps. The theme for spreading the technology is “the promotion to use the heat pump for water heating and air conditioning for industrial, commercial, and residential settings.” The theme for improving efficiency is “the promotion to research and develop next-generation heat pump systems (super high efficient heat pump).”
In addition, the New Growth Strategy, which indicates Japan’s grand policy, expressed the idea to build a strong country in the environmental and energy fields through green

innovation and established strategies to succeed in both economic growth and CO_2 reduction. Among these strategies, the New Growth Strategy proposes policies to promote zero emissions through the use of heat pumps, increase air thermal and geothermal uses, and expand the renewable energy market.

4.2 Incentives

Various incentives are available to promote the spread of the heat pump. Although the application is not necessarily limited to the heat pump, heat pump systems are receiving benefits from various subsidy programs because of the significant rate of CO_2 reduction. The District Heating and Cooling for 'Tokyo Sky Tree' Area in Figure 7, which receives a government subsidy, is using the geothermal heat pump system. It uses geothermal energy as the heat source for cooling and heating through the foundation pile method, which uses heat exchanger tubes attached to the foundation piles of the building, or the borehole method, which uses heat exchanger tubes inserted in vertically drilled holes. The district also plans to achieve more than 1.35 in annual total energy efficiency, the highest efficiency level in District Heating and Cooling in Japan, which is used along with the effect of a large thermal storage tank the size of seventeen 25-meter swimming pools."

Figure 7: District Heating and Cooling for 'Tokyo Sky Tree' Area

Heat pump systems are covered by tax incentive programs. The tax system to promote the reform of the supply-demand balance of energy gave incentives for specific heat pump systems for air conditioning and water heating as high-efficiency electric heat source systems until fiscal year 2010. Heat pump systems are expected to be covered by the new green investment tax incentive, which starts in fiscal year 2011. In addition, Kosugenoyu, the hot spring facility in Yamanashi, uses a heat pump system employing waste heat from the hot spring. This system recovers waste heat from hot tubs and showers and uses it as additional heat for heating water and keeping hot tubs warm. This facility uses the domestic credit system of the Ministry of Economy. Kosugenoyu sold certified amounts of CO_2 reduction calculated in comparison to boiler uses to a large company. Although the government has not implemented measures to strengthen regulations to promote the introduction of heat pump systems at this point, the government is considering strengthening system introduction regulations in addition to incentives in the future.

4.3 Research and Development

Cool Earth, the innovative technology plan that the Ministry of Economy, Trade and Industry established in 2008, stipulates the technological road map for super high efficient heat pump technology. This plan includes an extremely ambitious development goal to increase the term-based average efficiency by 1.5-fold from the current level by 2030 and by two-fold by 2050. Examples of breakthrough technologies that realize this development goal include expansion dynamics recovery technology, super high efficient heat exchanging technology, next-generation refrigerant technology, technologies that function in extremely cold regions, heat recovery technology, and technologies that employ unused heat. The plan also describes target costs, since price is an important factor in promoting the spread of heat pump systems. Achieving a dramatic improvement in efficiency in term averages, such as with the super high efficient heat pump, is difficult if we only focus on the technological development of the main aspects of the heat cycle. Thus, a wide range of technological developments is necessary, such as heat recovery technology, technologies that employ unused heat (solar thermal, geothermal, sewage thermal, groundwater thermal, etc.), and improvements in efficiency under low-load conditions. The Ministry of Economy, Trade and Industry started the Next-generation Heat Pump System Research and Development Project in fiscal 2010. This project selected nine projects and aims to improve term-based average efficiency by 1.5-fold from the current level by 2030. There are high expectations for these projects as combined efforts of industry, academia, and government.

5 DEFINITION OF RENEWABLE ENERGY

5.1 Legal Definitions

There are two types of laws that define renewable energy from the heat pump. The Act on the Promotion of the Use of Non-fossil Energy Sources and Effective Use of Fossil Energy by Energy Suppliers was established in July 2009 targeting suppliers of electric power, heat, oil, and gas. The cabinet order for this Act defines renewable energy sources. The Act defines aerothermal, hydrothermal, and geothermal heat as being “energy sources existing in the air and nature” along with wind power and solar heat.

Also, the Act on Special Measures to Promote the Use of New Energy (the New Energy Law) defines part of renewable energies. The Act covers renewable energy that can replace oil but has not become widespread due to lack of funds, but which is worth promoting. The definition is as follows. However, it excludes large-scale geothermal power generation, except binary-cycle plants and large-scale hydroelectric power generation with energy output of 1,000 kW or more.

(i) The production of fuel from organic substances derived from plants and animals that can be used as a sources of energy (excluding crude oil, petroleum gas, combustible natural gas and coal, and their products; referred to as “biomass” in the following item and item vi);
(ii) The use of biomass or fuel made from biomass to generate heat (excluding those listed in item vi);
(iii) The use of solar thermal energy for heating water, heating and cooling spaces, or other purposes;
(iv) The use of heat from seawater, river water, or other water sources utilizing a refrigeration facility;
(v) The use of heat from snow or ice (excluding ice produced utilizing refrigeration equipment) for refrigeration, cooling spaces, or other purposes;
(vi) The use of biomass or fuel made from biomass to generate electric power;
(vii) The use of geothermal energy to generate electric power (limited to electric power generation using ammonia-water, pentane, or other liquids with boiling points below 100 degrees at atmospheric pressure);

(viii) The use of wind energy to generate electric power;
(ix) The use of hydraulic energy to generate electric power (limited to electric power generation using a power generation facility installed in a structure used for irrigation, water-utilization, sediment control, or other purposes other than electric power generation having an output capacity of 1,000 kilowatts or less);
(x) The use of solar cells to generate electricity.

Although heat pumps employing hydrothermal heat are defined in section iv, this Act does not cover heat pumps that use aerothermal and geothermal heat.

5.2 Amount of the Use of Aerothermal in Japan

The formula (1) is used to calculate the amount of use of renewable energies from a heat pump as defined in EU Directives associated with the promotion of renewable energies.

$$E_{RES} = Q_{usable} * (1-1/SPF) \quad (1)$$

where
E_{RES}: The amount of renewable energy.
Q_{usable}: The estimated total usable heat delivered by heat pumps.
SPF: The estimated average seasonal performance factor for those heat pumps.

Table 2 shows the outcomes of the trial calculation of the amount of air heat used in three fields in Japan (residential room heating, residential water heating, and water heating for commercial use). The calculated number of household air conditioners in stock assumes that the average service life was 14 years. The number of household EcoCute units in stock is based on the record at the end of September 2010, and the number of heat pump water heaters for commercial use is based on the record at the end of fiscal year 2009. Although the use of air heat accounts for a large portion of room heating and water heating at this point, the amount of use may increase, since there is wide room for heat pump systems to spread for room heating in cold regions and for water heating.

Table 2: Outcomes of the calculation of the amount of air heat uses

	Stock Units	Aerothermal Heat (10^4GJ/y)
Residential room heating	1.0×10^8	8,000
Residential water heating	2.5×10^6	3,094
Water heating for commercial use	1.2×10^4	233

6 CONCLUSION

This report described the history of the improvement in heat pump efficiency and the spread of systems in Japan and introduced the trend of government policies based on the expectations for CO_2 reductions and economic growth. A comprehensive implementation of policies is required for the further spread of heat pump systems, and the government will possibly consider revising tax systems, subsidy systems, as well as strengthening regulations. More than 100 million GJ of air heat is currently used in room and water heating in Japan's residential sector, and the expansion of the amount of renewable heat can be expected through the spread of heat pump systems.

7 REFERENCES

HPTCJ 2007. “Heat Pumps: Long-Awaited Way out of the Global Warming”, Heat Pump & Thermal Storage Technology Center of Japan, Tokyo.
http://www.hptcj.or.jp/e/publication/hpe.html

IEEJ 2010. “EDMC Handbook of Energy & Economic Statistics in Japan”, The Institute of Energy Economics, Japan, Tokyo.

JRAIA 2010. “Statistical Releases”, The Japan Refrigeration and Air Conditioning Industry Association, Tokyo.

SGEIHP 2010. “The Economic Impact of The Heat Pumps Spread”, Study Group on Economic Impact of Heat Pumps (Heat Pump & Thermal Storage Technology Center of Japan, Japan Electro-Heat Center, Mitsubishi Research Institute, Inc.), Tokyo.
http://www.hptcj.or.jp/information/whatsnew_bn/topics101.html