THE NEWEST SITUATION AND THE FUTURE VIEW OF THE CO_2 REFRIGERANT HEAT PUMP WATER HEATER "Eco Cute" IN JAPAN

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Abstract: In January of 2001, for the first time in the world, Tokyo Electric Power Co., DENSO CORP., and Central Research Institute of Electric Power Industry have reported the practical application of the CO_2 refrigerant heat pump water heater for residential use, which can save more than 30% of energy compared to conventional combustion type water heater.

The government has started a subsidy system in September of 2002, and at the end of March, 2008, about 1,240,000 of the system have accumulatively forwarded to the whole market and now it continues to spread around well.

This paper deals with the newest situation of CO_2 refrigerant heat pump water heater "Eco Cute" in Japan, its widespread use situations, performance improvements achieved since introduction of the first model, variations, user evaluations, efforts by Tokyo Electric Power Company, programs for supporting the widespread use, challenging issues and future prospects.

Key Words: ***CO_2 refrigerant, heat pump water heater for residential use***

1 INTRODUCTION

Measures to cope with global warming issues are becoming increasingly important, and energy saving efforts and CO_2 emission reduction in the residential sector are also becoming urgent and important in Japan.

Energy consumption in the residential sector in Japan has increased by 1.7 times over the last 35 years. During this period, the Energy Saving Law was enforced in 1979, and the Energy Saving Standard for the residential sector was established at the same time (revised in 1994 and 2000) to promote reduction of air conditioning load. For lighting apparatus and electronic appliances, the so-called "Top Runner Program" was introduced in 1998 to establish the target of the performance of air conditioners, lightings, refrigerators, TVs and VTRs, and improvements of appliances efficiency have been promoted since then. Meanwhile, the "hot water supply" area that accounts for about 34% of final energy consumption in the residential sector largely depends on combustion of fossil fuels such as gas and oil. Emission reduction in this area is one of the major issues (Figure 1).

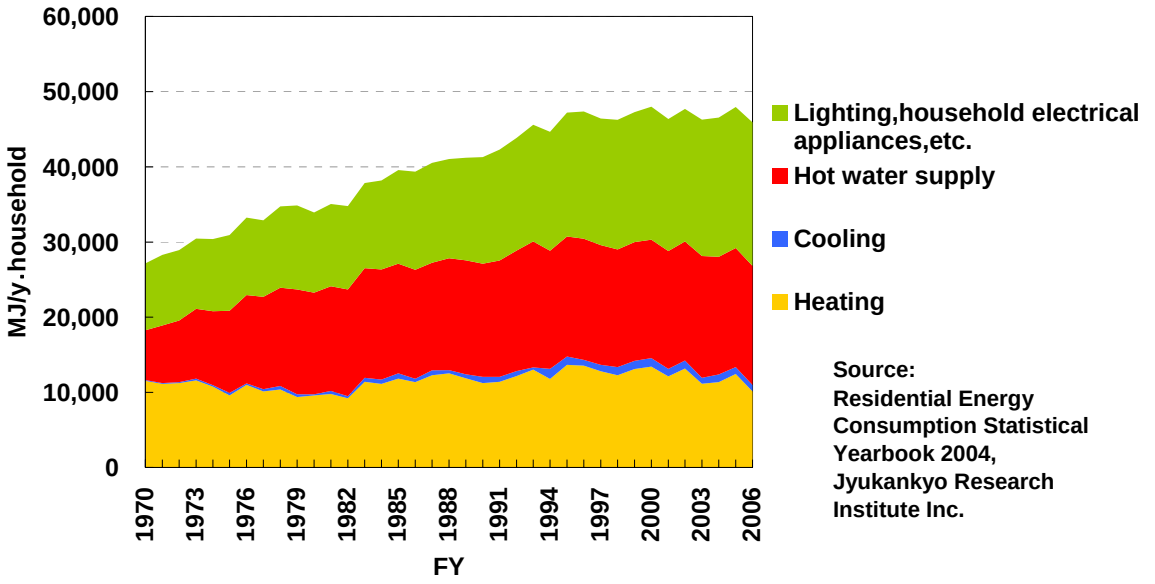


Figure 1: Breakdown and Changes of Energy Consumption in Residential Sector in Japan

The natural refrigerant (CO_2) heat pomp water heater "Eco Cute(*1)" is a high efficient hot water heater which is developed in an effort to achieve "energy saving in hot water supply systems."

"Eco Cute" (Figure 2) uses the natural refrigerant (CO_2) that has very little impact on global warming. This is an innovative, high-efficient water heater utilizing the principle of a heat pump that offers a very high coefficient of performance (COP).

Figure 2: Natural Refrigerant (CO_2) Heat Pump Water Heater "Eco Cute"

Its features are:
1) High efficiency
Based on the principle of a heat pump, it heats water by pumping out heat in the air, therefore, it can produce heat energy as much as 3 to 5 times of the energy (electricity) applied to it (Figure 3). Compared with a conventional combustion type water heater, it can save primary energy by about 30% and reduce CO_2 emissions by about 50% (Figure 4).

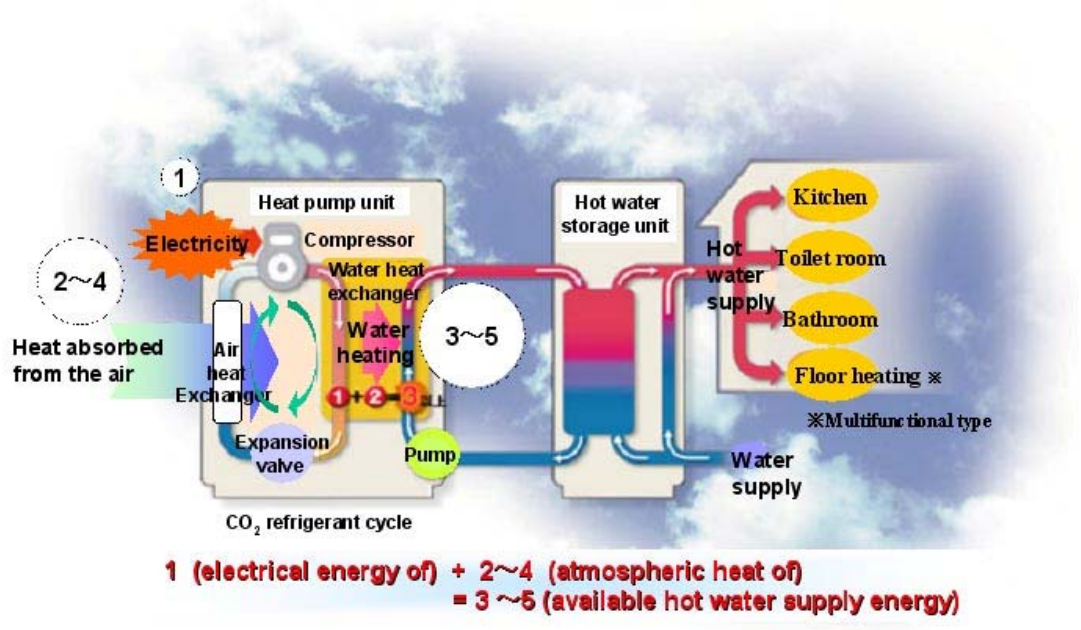


Figure 3: Principle of Natural Refrigerant (CO_2) Heat Pump Water Heater

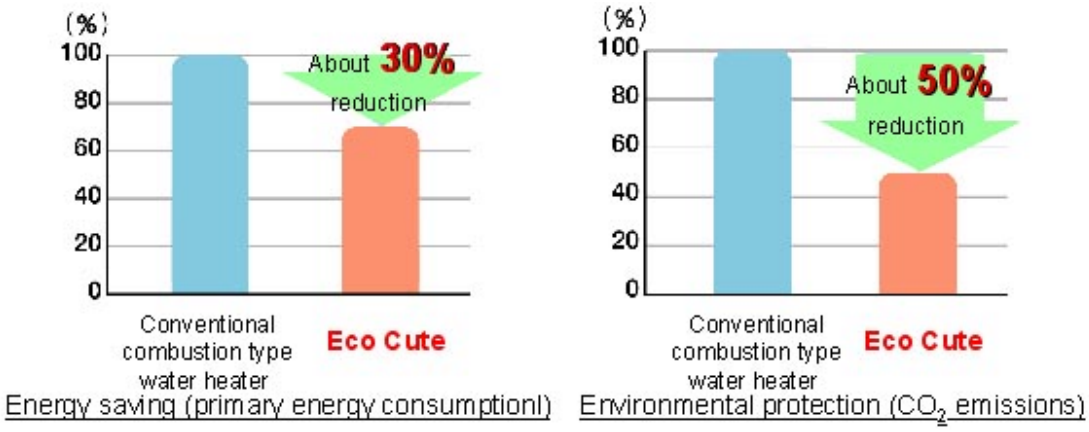


Figure 4: Energy Saving and Environmental Protection Performance

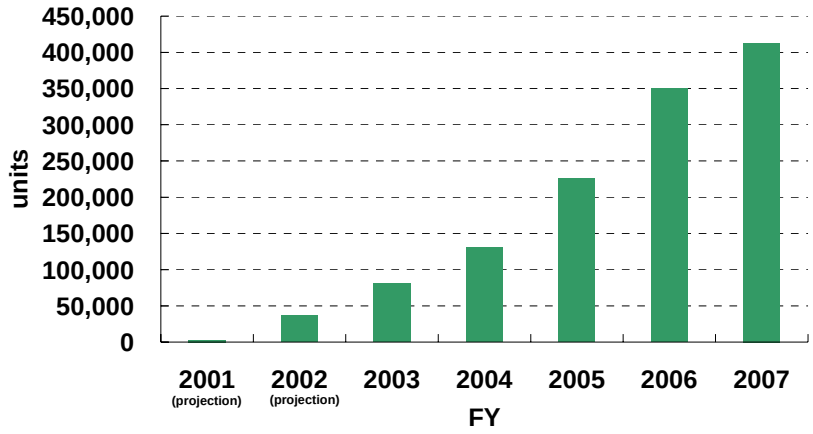
2) Natural refrigerants (CO_2)
Instead of using a fluorocarbon refrigerant as the refrigerant for the heat pump, it uses a natural refrigerant (CO_2) that has very little impact on global warming. It can heat water as high as up to a maximum of 90℃ by solely operating a heat pump due to the physical properties of CO_2 refrigerant.

3) Low running cost
By combining inexpensive electricity of the night-only service with the highly efficient heat pump system, it was able to achieve superior running cost performance as low as about \1,000 a month on average (*2).

2 THE SPREAD SITUATION OF "ECO CUTE"

It has been 7 years since DENSO CORP., Central Research Institute of Electric Power Industry and Tokyo Electric Power Company publicly announced the practical application as

their joint research in January 2001. “Eco Cute” is now sold by 16 manufactures for residential application and 17 suppliers for business application.
The government has started the subsidy system for commercial availability in September 2002 as the support measures to promote smooth introduction to the markets. Thanks to the effects of such measures, the shipments are increasing steadily. In fiscal 2007 only, about 413,000 units were shipped throughout the country and it is now reaching about 1,240,000 units in total (Figure 5).



Sources: Figures for 2001, 2002 and after are estimated by TEPCO, and those for 2003 and after are based on shipment statistical data published by the Japan Refrigeration and Air Conditioning Industry Association.

Figure 5: Shipments of “Eco Cute” (Nationwide)

The birth of “Eco Cute” marked the start of the “high-efficient water heater age.” Since then various water heaters have been developed, such as latent heat recovery type gas water heaters (2000), residential gas engine cogeneration systems (2003) and residential fuel cell systems (2005). Water heaters are making rapid progress in improving their efficiency. Comparing with widespread use of other high efficient appliances such as latent heat recovery gas water heaters which amount to 544,000 units, and residential gas engine cogeneration systems which amount to 55,000 units in total, respectively, it is clear that the high efficient water heater markets have been led by “Eco Cute”.

However, the government is intending to accelerate further spread of these water heaters. The documents released by the Demand and Supply Subcommittee of the Advisory Committee for Natural Resources and Energy said that the “Eco Cute” would be one of the pillars of the measures for energy saving in the home, together with the next generation energy saving standard house and Top Runner electric home appliances. In the case of additional measures, it is estimated that about 5.2 million units will be widely used by the year 2010. In addition, there is a scheme of expecting the spread of 14.3 million “Eco Cute” in residential application and 5.28 million in business application.

3 PERFORMANCE IMPROVEMENTS OF “ECO CUTE”

As the market for these products grows, competition among the suppliers is getting fierce. This has led to rapid progress in improvement of the heat pump unit performance and in reduction of operating noises.

COP (Coefficient of Performance) of the model (4.5 kW of the heating capacity) first introduced into the markets under the rated heating condition of the JRA (The Japan Refrigeration and Air conditioning Industry Association) has been improved from 3.5 to 5.1, the operating noises have been reduced from 45dB to 38dB. (Figure 6)

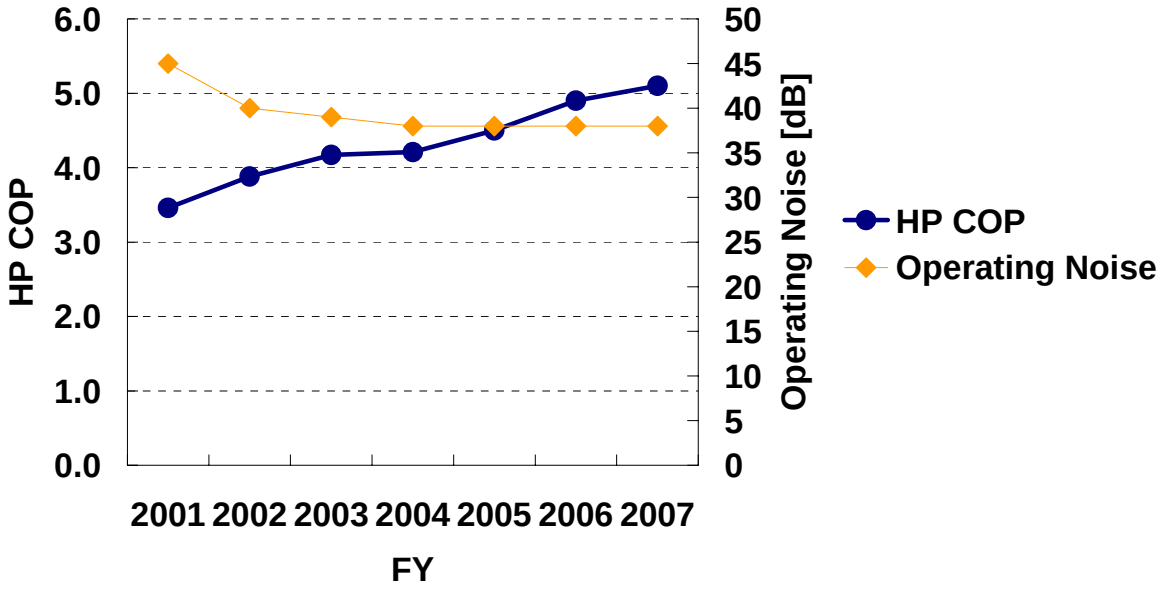


Figure 6: Progress in Performance Improvement of Heat Pump Units

4 VARIATIONS IN MODELS AND FUNCTIONS

The Japanese people are one of the most bath-loving people in the world, and therefore, there are many variations in models and functions of “Eco Cute”.

As a result of the market expansion, a wide range of variations are made available in models and functions of Eco Cute, as well. Table 1 shows models and functions of electric hot water heaters which are classified according to heating methods, heating capacities/hot water storage capacities, bath water heater types, maximum-pressure-applied (tap water) types, electricity contract options, additional functions (floor heating), shapes of hot water storage units, installation places and additional remote control functions, etc. Various types of “Eco Cute” that accommodate varying user needs are now available on the market.

Besides residential use “Eco Cute”, various types of institutional and business use “Eco Cute” depending on hot water supply loads for hospitals, sports facilities, industrial factories and restaurants have been placed on the market. More than 800 units have already been introduced.

Table 1: Model and Function Variations of "Eco Cute

Classification by heating system		Classification by heating and hot water storage capacity			Classification by system to supply hot water into bathtub	
Type	Refrigerant	Type	Rated heating capacity	Hot water storage capacity	Type	Function to supply hot water into bathtub
Heat pump	CO2	Heat pump water heater	4.5kW	300L	Full-automatic	With function to reheat hot water
	R410A		4.5kW	310L		With function to automatically keep hot
Electric heater			4.5kW	370L	Semi-automatic	With function to automatically supply hot water into bathtub
			6.0kW	460L	Hot water supplied directly from the tap into the bathtub	With function to stop supplying hot water when the bathtub is filled enough with hot water
			6.0kW	560L		Hot water supplied directly from the tap into the
			6.0kW MAX9kW	370L	Others	With function to inject oxygen into hot water
			6.0kW MAX10kW	150L		
		Electric heater	2.1kW	150L		
			2.4kW	200L		
			3.4kW	300L		
			4.4kW	370L		
			5.4kW	460L		
			6.4kW	550L		

Classification by maximum working pressure			Classification by electricity contract options			Classification by additional function (heating)	
Type		Pressure reducing valve	Type	Energization controlled	Energization not controlled	Type	Additional function (heating)
End stop (pressure reducing valve system)	High pressure type (up tp 200kPa)	170kPa	Time-of-use (TOU) lighting only	○		Hot water supply only	
		150kPa				Hot water supply and heating (multifunctional)	Hot water supply + floor heating + bathroom drying
	Standard pressure type (up to 100kPa)	85kPa	Switchable between TOU and nighttime power	○			Hot water supply + floor heating
Main stop			Nighttime power only	○	○		Hot water supply + bathroom drying

Classification by shape of hot water storage unit		Classification by place of installation			Classification by remote-controlled additional function	
Type	Number of tank(s)	Conditions	Specifications		Remotely controlled or not remotely controlled	Additional function (remotely controlled)
Built-in pipe type (square-shaped	Single-tank type	Weather conditions	Cold climate areas (I&II areas)		Remotely controlled	With IT function
	Double-tank type		General areas (III areas)			With interactive conversation function
Externally installed pipe type (round-shaped type)		Salt damage conditions	General areas			With one-way speech function
			Salt damage areas			
			Heavy salt damage areas			
		Dwelling unit conditions	Detached houses	Outdoor	Not remotely controlled	With navigation function
				Under the eaves		Standard functions only
				Indoor	Not remotely controlled	
			Apartments			

Eco Cute

5 ACTIVITIES BY TEPCO IN DEVELOPMENT AND PERFORMANCE IMPROVEMENTS

5.1 "Eco Cute" development involved by TEPCO

Tokyo Electric Power Company started the joint study with DENSO CORPORATION and Central Research Institute of Electric Power Industry in October, 1998, and publicly announced the world's first practical application of natural refrigerant (CO_2) heat pump water heaters for residential application in January, 2001. TEPCO is not engaged in manufacturing and marketing water heaters as a water heater supplier. However, TEPCO is working hard for improvement of the performance and functions of "Eco Cute", and continually making business proposals to encourage house builders and developers to adopt "Eco Cute".

In 2002, TEPCO developed “a slim type for use in apartments” which made installation in apartments possible. In 2003, TEPCO developed “a multifunctional type (for both hot water supply and room heating)” that accommodates the growing needs for floor heating. In 2006, “Design Eco Cute” which is provided with good design and easy to use, was developed to match the view of houses in urban areas. TEPCO has been conducting the joint development to meet varying needs, and products meeting these needs are now made available in the market by the above mentioned water heater suppliers.

5.2 Activities for performance improvement

Improvement of appliance efficiency is also one of the important themes of the joint research.

For improvement of appliance efficiency, it is essential to have the basic data on how the water heaters and heating systems are used by users. From this reason, water heater loads have been measured at more then 90 households so far.

From April 2005 to March 2007, the actual system COP was measured in 36 households (average family members: 3.7) in Kanto, Chubu, Kansai, and Chugoku regions for about 7 months to 12 months. The average of amount of hot water at the temperature of 40℃ in every periods (rated, winter, summer) was 422L/day and the average of the standard deviation in periods was 70 to 100L/day in each household. The result showed variation but the hot water load was almost the same as that of the L mode of IBEC(*2). Figure7 shows annual average of hot water load and actual system COP. These examples are all used in optimal heating mode of hot water load.

The annual average of actual system COP of 36 households was about 3.16 (1.16 at primary energy consumption).

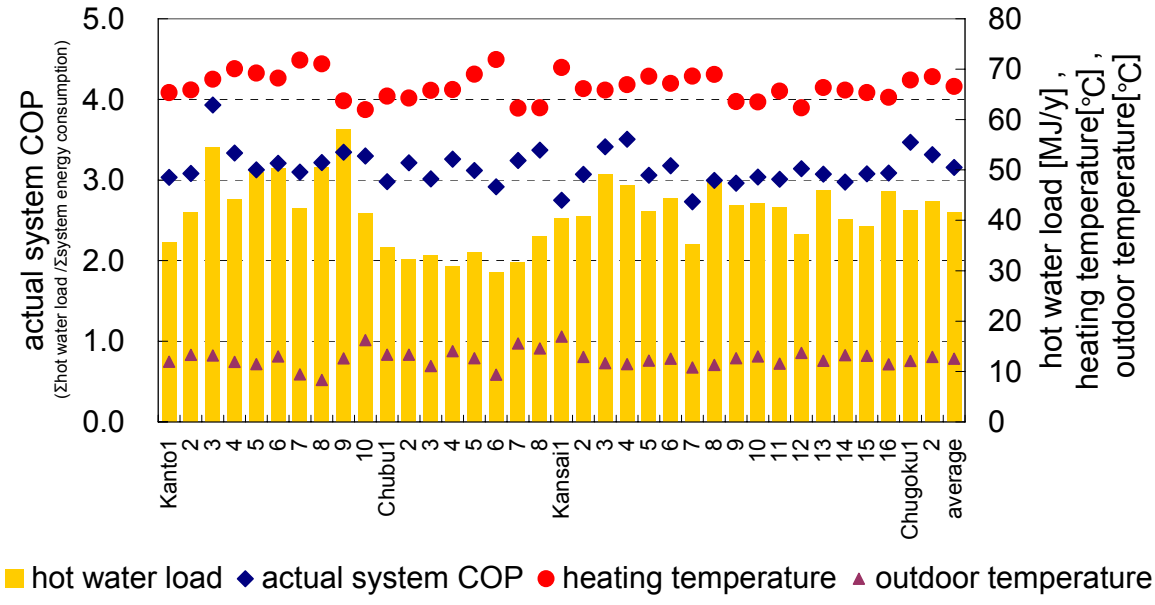


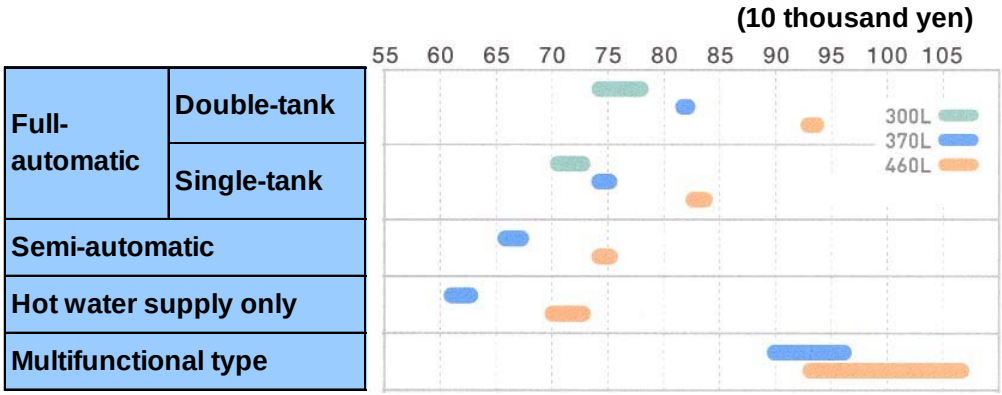
Figure 7: Annual average of hot water load and actual system COP

These measurements data has been used to improve the accuracy of the “learning function” that can predict the heat water loads of individual household to perform optimal water heating.

6 SUPPORTING PROGRAMS FOR SPREADING "ECO CUTE"

6.1 Subsidy Programs

"Eco Cute" is a high efficient water heater which is effective for global warning control, however, the appliance is more expensive than a conventional combustion water heater. From this reason, the government's subsidy program has started in 2002. The national budget appropriated for this subsidy program in 2008 amounts to 10.8 billion yen, and it provides 42,000 yen per one unit (for houses).



*Eco Cute of major suppliers were surveyed.
*The yardstick prices are suppliers' proposed retail prices (tax included)
*The above prices include a remote controller of the standard type.
The data from TEPCO (December 2007)

Figure 8: Yardstick of Eco Cute price range (based on retail price)

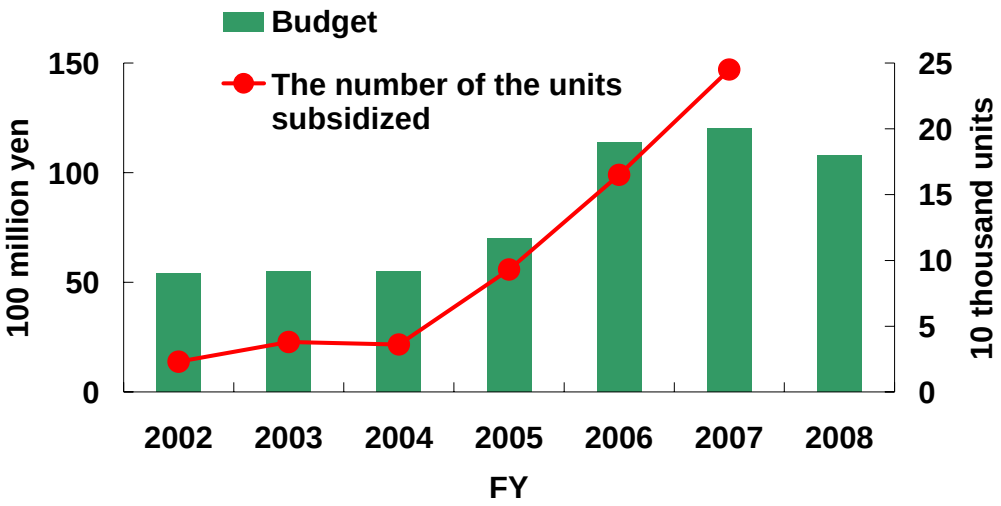


Figure 9: Transition of a subsidy budget

In addition, "Promotion of High Efficient Energy System Introduction to Houses and Buildings" by NEDO (New Energy and Industrial Technology Development Organization), and other support programs by the local governments are offering the subsidies for using "Eco Cute" in some cases. These subsidies are effective measures in promoting widespread use of "Eco Cute".

6.2 Housing loan preferential interest rates

The growing number of banks now has the plans to substantially reduce the interest rate of the loans for building, purchasing and reforming Totally Electrified Houses.

Besides, fire risks of Totally Electrified Houses are much less than that of the houses using both gas and electricity systems, therefore, some insurance companies started to offer discounts of fire insurance. Use of these preferential financial products can offset cost increase caused by purchase of “Eco Cute”.

7 ISSUES AND PROSPECTS OF “ECO CUTE”

7.1 Furnishing information to “Eco Cute” users

COP of “Eco Cute” shown in catalogues of the suppliers is measured in accordance with The Japan Refrigeration and Air Conditioning Industry Association Standard (JRA-4050:2007R) at the temperatures shown in the Table 2. Eco Cute consists of the heat pump unit and the tank unit, and this shows the energy efficiency of only the heat pump unit. COP varies depending on the outside air temperatures, feed-water temperatures, heating temperatures, and heating mode (temperature, amount of heat, etc.). From this reason, COP of “Eco Cute” in actual use may differ from COP given in the suppliers’ catalogues.

Table 2: JRA-4050:2007R test conditions

	Outdoor temperature		Temperature of cold water supply	Temperature of outgoing hot water
	DB	WB		
Rated heating condition	16	12	17	65
Heating condition during winter	7	6	9	Highest heating temperature (≒90)
Defrosting condition during winter	2	1	5	---
Heating condition during summer	25	21	24	65

From April 2008, “Eco Cute” catalog will start to indicate the “Annual performance factor of hot water supply (APF)” as well as COP so as to show the efficiency of hot water system as a whole to evaluate the energy saving much closer to using condition. APF is indicated according to JRA 4050 : 2007R (for heat pump water heater in residential use). The annual amount of heat used in hot water is divided by necessary energy consumption in same period. This shows the efficiency of hot water system as a whole when used in heating mode of optimal hot water load.

To keep the performance of energy saving, it is necessary to use in optimal heating mode of hot water load. It is future issue to easily furnish information about how to use “Eco Cute” well to users.

7.2 Challenging issues for promoting widespread use and future prospects

In March 2005, the private study group “CO_2 Refrigerant Heat Pomp Water Heater Promotion Study Group” established under the sponsorship of the Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry made proposals for achieving

government's target "introduction of approximately 5.2 million units in 2010." According to their proposals, the issues to be addressed for increasing the use of "Eco Cute" are reduction in the initial cost, reduction in the appliance size, applicability in the cold regions and simplified installation. And also the activities were shown to the government, electric power companies, and appliance suppliers to accomplish the goal.

Regarding to the reduction in the appliance size, applicability in the cold regions and simplified installation, the result of the research and development carried out in NEDO was already beginning to be sold and further spread is expected.

8 CONCLUSION

This report describes the natural refrigerant (CO_2) heat pump water heater "Eco Cute," particularly its development background, widespread use situations, performance improvements, types and variations, user evaluations, efforts by TEPCO, programs for supporting the widespread use over 7 years since it was first introduced into the markets in Japan, challenging issues and future prospects.

The shipments are favorably increasing, performances are improving and more variations in the models and functions are becoming available. These water heaters are highly evaluated by many users now.

To achieve more accelerated use of "Eco Cute", the government, suppliers and electric power companies are making efforts together in Japan.

REFERENCES

Hajime Akahane, Hirofumi Ida, Katsuya Morimoto, Mari Miyata, and Hiroyuki Inagaki, 2007, "Survey & evaluation of the CO_2 refrigerant heat pump water heater in actual houses: Parts 1 and 2", The paper for lecture presented at an academic lecture meeting of The Society of Heating, Air-Conditioning and Sanitary Engineers of Japan.

*1: "Eco Cute" is the name used by the electric power companies and water heater manufactures when they call the natural refrigerant (CO_2) heat pump water heaters.

* 2: Calculation conditions
The electricity rate: Tokyo Electric Power Company's "Season and Time-Specific Lighting (Denka-Jozu)" (the discount for fully-electrified homes and the discount for energization-controlled nighttime thermal storage type appliances are applied. In this case, an amount due to the fuel cost adjustment is not applied).
The electric power consumption is based on the condition below:

1.The equivalent hot water amount at the temperature of 43℃ on the L mode of IBEC (Institute for Building Environment and Energy Conservation) is used for the standard water heater load.
2. The outside air temperature and the feed water temperature are based on the standard of The Japan Refrigeration and Air conditioning Industry Association (JRA4050:2007R).
3. Equipment efficiency, defrosting and boiling out loss are included in the calculation.
4. The calculations are made on the electric power consumption of three periods; shoulder, winter and summer seasons.
The electricity cost required for heat retention of bathtub water is not included. The actual running cost of the water heater may vary depending on the amount of hot water consumed, family structures and seasons.