Data 2

Final Report by Heat Pump Water Heater Evaluation Standards Subcommittee, Energy Efficiency Standards Subcommittee of the Advisory Committee for Natural Resources and Energy

September 11, 2012

Ministry of Economy, Trade and Industry

The heat pump water heater evaluation standards subcommittee deliberated on evaluation standards, etc. for manufacturers and importers of heat pump water heaters (hereinafter referred to as “manufacturers, etc.”) for the purpose of improving the performance of these products (the deliberation included the scope, categories, target fiscal year, target standard values, measurement methods, etc. of heat pump water heaters covered in this report) and prepared this interim report as follows.

1. Target scope [See Attachment 1]

Heat pump water heaters covered by this time are all of the residential heat pump water heaters using CO_2 as refrigerant. However, products equipped with a function to use heat generated by the heat pump not only for hot water supply or heat-retention of bath water but also for space heating such as floor heating are excluded from the scope.

2. Matters to be considered as evaluation standards for manufacturers, etc.

(1) Target fiscal year [See Attachment 2]

Target fiscal year for the heat pump water heaters is set as FY2017.

(2) Categories for setting targets and target standard values [See Attachment 3 and Attachment 4]

Regarding heat pump water heaters shipped by manufacturers, etc. to the domestic market in the target fiscal year, the weighted average values of energy consumption efficiency of these products obtained by the method stated in paragraph (3) below, where said weighted average values are calculated using the number of products shipped in each category as shown in Table 1 per manufacturer, shall not be below the appropriate target values.

Table 1 Standard Energy Consumption Efficiency of Heat Pump Water Heaters

Category	Assumed household type	Hot water storage capacity	Intended area	Heat-retention function	Number of tanks used for storing hot water	Standard energy consumption efficiency
1	Standard	Below 240 L	Normal area	With	Single	2.8
2					Multi	2.4
3				Without	Single	3.0
4					Multi	2.6
5			Cold area	With	Single	2.3
6					Multi	2.0
7				Without	Single	2.6
8					Multi	2.3

9	Standard	240 L or above, below 320 L	Normal area	With	Single	2.8
10					Multi	2.8
11				Without	Single	3.2
12					Multi	2.8
13			Cold area	With	Single	2.3
14					Multi	2.0
15				Without	Single	2.7
16					Multi	2.3
17		320 L or above, below 550 L	Normal area	With	Single	3.3
18					Multi	2.8
19				Without	Single	3.2
20					Multi	2.8
21			Cold area	With	Single	2.7
22					Multi	2.3
23				Without	Single	2.7
24					Multi	2.3
25		550 L or above	Normal area	With	Single	2.9
26					Multi	2.5
27				Without	Single	2.9
28					Multi	2.5
29			Cold area	With	Single	2.4
30					Multi	2.1
31				Without	Single	2.5
32					Multi	2.2
33	Fewer family members	–	Normal area	With	–	2.4
34				Without		2.8
35			Cold area	With		2.0
36				Without		2.4

Note 1 “Hot water storage capacity” refers to the capacity of a tank unit which is capable of storing hot water defined in the “Residential Heat Pump Water Heaters” of Japanese Industrial Standard C 9220 (hereinafter referred to as JIS C 9220).

Note 2 “Cold area” refers to a specification of a product which is designed and produced on the assumption that it will be used in an area where the weather is severely cold in winter, as defined in JIS C 9220.

Note 3 “Heat-retention function” refers to a function which circulates and heats bath water.

(3) Method for measuring energy consumption efficiency [See Attachment 5 and Exhibit]

Energy consumption efficiency of a heat pump water heater is the ratio of heat quantity transferred to circulating hot water to electric power consumption per time unit when the heat pump is operating. It is expressed as "annual water heating and heat-retention efficiency" in case of heat pump water heaters with a bath water heat-retention function and as "annual water heating efficiency" in case of those without said function, both of which shall be measured by the method stipulated by JIS C 9220 and calculated by the following formulae.

<Those with a bath water heat-retention function>

$$\text{Annual water heating and heat-retention efficiency} = \frac{\text{Heat quantity acquired by hot water used in a year} + \text{Heat quantity acquired by bathtub water for heat-retention (MJ)}}{\text{Annual energy consumption (kWh)} \times 3.6}$$

<Those without a bath water heat-retention function>

$$\text{Annual water heating efficiency} = \frac{\text{Heat quantity acquired by hot water used in a year (MJ)}}{\text{Annual energy consumption (kWh)} \times 3.6}$$

(4) Items to be indicated, etc.

1) Items to be indicated

Items to be indicated are as follows.

i) Product name or model name
ii) Category
iii) Energy consumption efficiency (annual water heating and heat-retention efficiency or annual water heating efficiency)
iv) Name of manufacturer, etc.

2) Matters to be complied with

1. Annual water heating and heat-retention efficiency and annual water heating efficiency shall be indicated up to the first decimal place.
2. Items listed in the paragraph 1) above shall be indicated in catalogues and operation manuals describing the performance of product at the place which is easy to see and helps consumers choose products.
3. If a product is equipped with a bath water heat-retention function, annual water heating and heat-retention efficiency must be indicated. If not equipped with the function, annual water heating efficiency must be indicated.
4. If a product is intended for cold area, it must be clearly mentioned that the specification is for use in cold areas, and its annual water heating and heat-retention efficiency or annual water heating efficiency under the cold area condition shall be indicated.

3. Proposals for energy conservation

(1) Actions of Government

1) From viewpoint of aiming at the dissemination of heat pump water heaters with excellent energy consumption efficiency, efforts shall be made to take necessary measures such as spreading and enlightenment activities, in order to promote actions of users and manufacturers, etc.
2) Implementation status of information indication which is to be performed by manufacturers, etc. shall be checked periodically and continuously. Also, appropriate law management shall be made so that correct and easy-to-understand information regarding energy consumption efficiency can be provided for users.
3) As regards categories for which no product currently exists, necessity of making such categories and adequacy of their standard values shall be studied based on the future trend of product development, etc. by manufacturers, etc.
4) Energy efficiency standards based on the Top Runner method is a very effective means to reduce energy consumption of products; therefore, efforts shall be made to disseminate it internationally by catching appropriate opportunities.

(2) Actions of manufacturers, etc.

1) Efforts shall be made to promote technological development for further energy saving of heat pump water heaters and to develop products with excellent energy consumption efficiency.
2) From viewpoint of aiming at the dissemination of heat pump water heaters with excellent energy consumption efficiency, efforts shall be made to provide appropriate information to encourage users to select such heat pump water heaters, for example by using “energy-saving labels”, etc. When using the energy-saving labels, consideration shall be given to the indicated items so as to be comprehensible for and not to cause misunderstanding among users.
3) Efforts shall be made to provide users with information about how to use products in a way that contributes to energy saving.

(3) Actions of users

1) Efforts shall be made to select heat pump water heaters with excellent energy consumption efficiency through effective use of information such as “energy-saving labels”, etc. At the same time, when using heat pump water heaters, efforts shall also be made to reduce energy consumption by appropriate and effective use of them, which includes active use of energy-saving setting, etc.
2) In order to maximize the performance of products, efforts shall be made to select heat pump water heaters based on the conditions of households and environment in which products are intended to be used.

(4) Actions of retailers

1) Efforts shall be made to sell heat pump water heaters with excellent energy consumption efficiency as well as to provide appropriate information to users by

utilizing “energy-saving labels”, etc. so that they would select such heat pump water heaters. When using the energy-saving labels, consideration shall be given to the indicated items so as to be comprehensible for and no to cause misunderstanding among users.

2) For appropriate information provision to users at stores, etc., efforts shall be made to collect information on energy saving of heat pump water heaters as well as to train sales people for this purpose.
3) Business operators who sell and build heat pump water heaters into buildings shall also make efforts to choose and install products with excellent energy consumption efficiency so that dwellers of the buildings will utilize such water heaters.

Attachment 1

Target Scope of Heat Pump Water Heaters

1. Basic idea

Heat pump water heaters covered by this study are all of the residential heat pump water heaters using CO_2 as refrigerant.

However, those 1) which are used for special applications, 2) for which technical methods for measurement and/or evaluation have not been established and 3) whose penetration rate in the market is extremely low shall be excluded from the scope, and specifically products described in the following paragraph 2 are excluded. Note that even though the following products are not included in the scope, 99% of the heat pump water heaters shipped is covered by this study.

2. Products excluded from the scope

Of the residential heat pump water heaters covered by this study, those which use the heat generated by the heat pump not only for water heating and heat-retention for bath water but also for space heating such as floor heating, etc. are excluded from the scope. It is because methods for measuring their energy consumption efficiency accounting for the space heating function have not been established and also because their shipment volume is extremely low.

* Estimated number of products shipped (FY2009): 5.3 thousand units
(Ratio to the total number shipped: Approx. 1.0%)

Attachment 2

Target Fiscal Year, etc. of Heat Pump Water Heaters

1. Target fiscal year

In the case of heat pump water heaters, it usually takes approximately 2 to 4 years to develop a new model; therefore, it is necessary to give consideration so that there are at least a few opportunities for manufacturers to develop new models by the target fiscal year. As such, it is reasonable to set the target fiscal year as FY2017, which is 8 years from the reference fiscal year (FY2009).

2. Improvement in target fiscal year

Improvement ratio in the target fiscal year is estimated to be 27% based on the premise that the number of products shipped and the product composition of each category in the reference year (actual figures of FY2009) remain unchanged.

<Outline of estimation>

(1) Energy consumption efficiency calculated from the actual figures of heat pump water heaters shipped in the reference fiscal year (FY2009): 2.49

(2) Energy consumption efficiency per unit calculated by weight-averaging target standard values with shipment volume of heat pump water heaters expected to be shipped in the target fiscal year: 3.16

(3) Improvement ratio of energy consumption efficiency

$$\frac{3.16 - 2.49}{2.49} \times 100 = \text{Approximately } 27\%$$

Attachment 3

Categories for Setting Target for Heat Pump Water Heaters

1. Basic idea

Heat pump water heaters shall be classified based on the principles referred to as "the basic idea concerning the development and revision of evaluation standards for manufacturers, etc. to be considered in relation to the improvement in performance of specific equipment" (the 10th Energy Efficiency Standards Subcommittee of the Advisory Committee for Natural Resources and Energy, revised on June 18, 2007) (hereinafter referred to as "the principles").

"The basic idea concerning the development and revision of evaluation standards for manufacturers, etc. to be considered in relation to the improvement in performance of specific equipment"
- Extract -

Principle 2: Specific equipment is classified based on certain indices. The indices (basic indices) are those which are deeply related to energy consumption efficiency such as physical amount and functions, and they are determined considering factors which consumers use as criteria when choosing products (factors representing consumers' needs).

Principle 3: Target standard value is determined as one value or by functional formula for each category based on the basic indices, for which it is feasible and appropriate to target at the same energy consumption efficiency.

Principle 4: When setting categories, additional functions are disregarded in principle. However, there is a case where, if the energy consumption efficiency of a product without a certain additional function is set as a target standard value, other products with the additional function may have to withdraw from the market because they cannot comply with the target standard value, despite that market needs for the latter products are thought to be high. If the probability of such case is high, then it is acceptable to make another category (sheet) for those products.

Principle 5: As regards products which are expensive but excellent in energy consumption efficiency because of using advanced energy saving technologies, although it is possible to classify them into a separate category, it is desirable to treat them in the same category with others wherever possible so that manufacturers can actively sell the products with excellent energy consumption efficiency.

Principle 6: When setting a target standard value for a category, special products shall be excluded. However, availability of technologies employed in such special products shall be also reviewed when studying the future efficiency improvement possibly realized by technology development, etc.

2. Specific classification method

Heat pump water heaters shall be classified by the following five factors based on product features.

- Classification by assumed household type
- Classification by hot water storage capacity
- Classification by intended area
- Classification by availability of heat-retention function
- Classification by the number of hot water storage tanks

(1) Classification by assumed household type (standard or fewer family members)

Heat pump water heaters are developed not only for standard households (4 family members) but also for households with fewer family members (2 people households), and measurement methods have also been established for both types. These household types have differences in the amount of hot water used, and their measurement modes are also different. Thus, products shall be classified by the type of a household assumed at the time of designing.

(2) Classification by hot water storage capacity

Heat pump water heaters are marketed having water storage capacity that corresponds to their installation spaces and hot water amount to be used. Based on the difference in capacity, the heating capability of heat pumps, the heat-up temperature setting and the heat-up time zone of hot water tanks, etc. vary model by model, which in turn affect the performance of heat pump water heaters. Therefore, heat pump water heaters shall be classified by hot water storage capacity. Main features of heat pump water heaters for standard households classified by hot water storage capacity are shown in Table 3-1.

As regards heat pump water heaters for households with fewer family members, they have been introduced in the market with a hot water storage capacity of approximately 200 L. Considering the amount of hot water to be used, diversification of the hot water storage capacity cannot be expected hereafter; thus, the products are not classified by this factor.

(3) Classification by intended area (normal area or cold area)

Heat pump water heaters intended for cold area are, anticipating the use in the severe winter weather, designed and manufactured differently from those intended for normal area, and accordingly their evaluation methods are also different. Thus, heat pump water heaters shall be classified by intended area.

(4) Classification by the availability of heat-retention function (with or without)

Heat pump water heaters can be classified into those with a function to circulate and heat bath water and those without such function. The former needs to apply heat to bath water to perform its heat-retention function; accordingly, electric energy consumption of these two types of heat pump water heaters is different. Thus, they shall be classified by the availability of heat-retention function.

(5) Classification by the number of hot water storage tanks (single or multiple)

Heat pump water heaters can be classified into those with a single hot water storage tank and those with multiple hot water storage tanks. The latter is intended to have the hot water storage unit thinner by means of containing multiple tanks of small capacity, considering the space where the product to be installed. Compared with heat pump water heaters with single storage tank, products with multiple tanks have larger heat discharge area; as a result, their heat-retention performances as well as efficiencies are lowered. Thus, they shall be classified by the number of hot water storage tanks.

As regards heat pump water heaters for households with fewer family members, they have been introduced in the market with a hot water storage capacity of approximately 200 L. Considering the amount of hot water to be used, diversification of the number of hot water storage tanks cannot be expected hereafter; thus, the products are not classified by this factor.

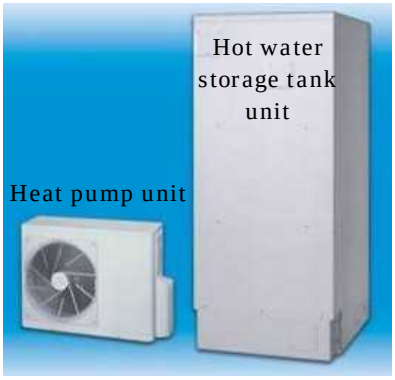


Table 3-1 General Characteristics based on Hot Water Storage Capacity (For Standard Households)

Main characteristics \ Tank capacity	Below 240 L	240 L or above, below 320 L	320 L or above, below 550 L	550 L or above
Heating-up time zone	Besides during nighttime, daytime heating-up is also performed (according to the time zone when hot water is used).	Standard (mainly heating-up during nighttime)		
Effect on efficiency	+	Standard		
Heating capability of heat pump unit	Being set at high so that plenty of water can be heated in a short period of time to prevent running-out of hot water.	Standard		Being set at high in order to accommodate a larger family consisting of 5 to 7 members.
Effect on efficiency	−	Standard		−
Heating-up temperature of tank unit	Standard	As tank capacity is slightly small, heating-up temperature is set at high to compensate it.	Standard	Standard
Effect on efficiency	Standard	−	Standard	Standard
Heat quantity discharged from tank	Small	Slightly small	Standard	Large
Effect on efficiency	+	+	Standard	−
Major tank capacity commercially available	180 L	300 L	370 L 460 L	550 L

3. Summary of classifications

Based on the indices mentioned in the paragraph 2, categories are set as shown in Table 3-2 (assumed household type: standard) and Table 3-3 (assumed household type: fewer family members).

Table 3-2 Categories of Heat Pump Water Heaters
(Assumed Household Type: Standard)

Category	Hot water storage capacity	Intended area	Heat-retention function	Number of hot water storage tanks
1	Below 240 L	Normal area	With	Single
2				Multiple
3			Without	Single
4				Multiple
5		Cold area	With	Single
6				Multiple
7			Without	Single
8				Multiple
9	240 L or above, below 320 L	Normal area	With	Single
10				Multiple
11			Without	Single
12				Multiple
13		Cold area	With	Single
14				Multiple
15			Without	Single
16				Multiple
17	320 L or above, below 550 L	Normal area	With	Single
18				Multiple
19			Without	Single
20				Multiple
21		Cold area	With	Single
22				Multiple
23			Without	Single
24				Multiple
25	550 L or above	Normal area	With	Single
26				Multiple
27			Without	Single
28				Multiple

29		Cold area	With	Single
30				Multiple
31			Without	Single
32				Multiple

Table 3-3 Categories of Heat Pump Water Heaters (Assumed Household Type: Fewer Family Members)

Category	Intended Area	Heat-retention function
33	Normal area	With
34		Without
35	Cold area	With
36		Without

[Reference]

[Specifications for normal area]

Intended area	Assumed household type	Heat-retention function	Number of tanks	Below 240 L	240 L or above, below 320 L	320 L or above, below 550 L	550 L or above
Normal area	Standard	With	Single	Category 1	Category 9	Category 17	Category 25
			Multiple	Category 2	Category 10	Category 18	Category 26
		Without	Single	Category 3	Category 11	Category 19	Category 27
			Multiple	Category 4	Category 12	Category 20	Category 28
	Fewer family members	With	—	Category 33			
		Without	—	Category 34			

[Specifications for cold area]

Intended area	Assumed household type	Heat-retention function	Number of tanks	Below 240L	240L or above, below 320L	320L or above, below 550L	550L or above
Cold area	Standard	With	Single	Category 5	Category 13	Category 21	Category 29
			Multiple	Category 6	Category 14	Category 22	Category 30
		Without	Single	Category 7	Category 15	Category 23	Category 31
			Multiple	Category 8	Category 16	Category 24	Category 32
	Fewer family members	With	—	Category 35			
		Without	—	Category 36			

Attachment 4

Target Standard Values for Heat Pump Water Heaters

1. Basic ideas

Target standard values are set based on the idea of Top Runner method. The specific ideas are as follows.

1) Target standard values shall be set for every category that has been defined appropriately.
2) As for categories where technological advances in the future are expected to improve the efficiency of products, target standard values shall allow for improvement as much as possible.
3) Target standard values shall not conflict with each other among categories.

2. Calculation of specific target standard values (standard energy consumption efficiency)

(1) Specific technologies for improving energy consumption efficiency and room for improvement

When setting target standard values for heat pump water heaters, efficient improvement technologies which are expected to be applied were studied. The structure of a heat pump water heater can be divided into the heat pump side for heating water and the hot water storage tank and supply circuit side for storing and supplying hot water. On the one hand, substantial efficiency improvement has so far been made for the heat pump side, because technologies similar to those adopted in air conditioners, which have already been designated as Top Runner Equipment, are used. On the other hand, as regards the hot water storage tank and supply circuit side, improvement can be expected using energy saving technologies such as (a) improvement of thermal insulation materials, (b) installation of a circuit for taking out medium temperature water and (c) improvement of heating-up control. Specific contents of these technologies are as follows.

(a) Improvement of thermal insulation (See Figure 3-1)

The function of a hot water storage unit is to store heated-up water and keep it hot until it is supplied and used. Therefore, thermal insulation of this unit greatly contributes to the energy saving of heat pump water heaters, and covering up the tank body with a thermal insulation material is commonly-used as a technique to realize it. Improvement can be achieved through controlling heat discharge from the hot water storage tank by means of using a highly-efficient thermal insulation material such as vacuum thermal insulation material in addition to conventional expanded polystyrene thermal insulation materials (foamed polystyrene).

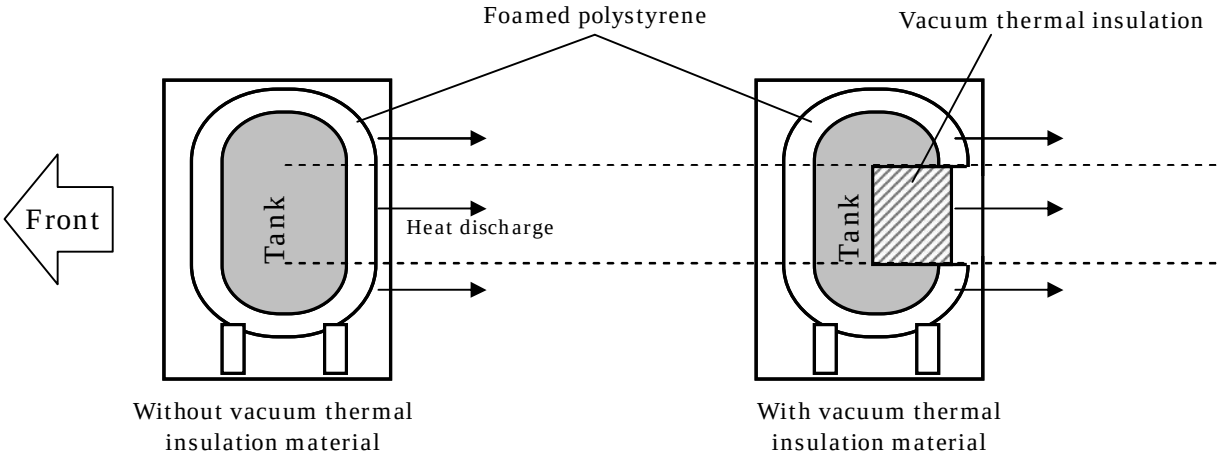


Figure 3-1 Image of Improvement of Thermal Insulation of Hot Water Storage Tank (Example)

(b) Installation of a circuit for taking out medium temperature water (See Figure 3-2)

A tank equipped in a hot water storage unit has a structure where high temperature hot water stays at the upper part and colder water stays at the lower part, and there is a layer of medium temperature water between them. When performing heat-retention of bath water, the high temperature hot water in the tank is used; consequently, the volume of the medium temperature water increases. If this medium temperature water is supplied to the heat pump and heated, the efficiency deteriorates. However, the hot water heat and heat-retention efficiency can be improved by taking out this water preferentially to be used at lavatory, shower, kitchen, etc.,

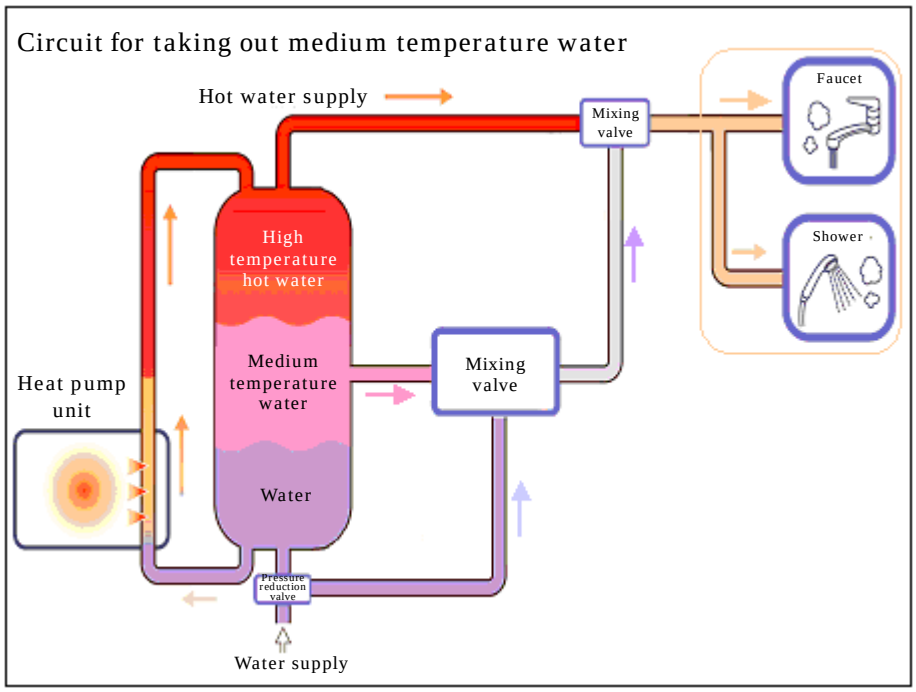


Figure 3-2 Circuit for Taking-out Medium Temperature Water

(c) Improvement of heating-up control

Heat pump water heaters generally make hot water at night (11:00 p.m. to 7:00 a.m.). By mixing the high temperature hot water stored in the tank with low temperature tap water, it supplies hot water at a certain temperature which is preset by a remote controller. Many heat pump water heaters are equipped with a learning function which is unique to each manufacturer to estimate a hot water amount used in a day and to heat water at an appropriate temperature, thereby reducing the loss caused by heat discharge.

At the same time, they constantly monitor the hot water amount in their tank unit as well as the hot water amount used. If it is found that the hot water amount stored in the tank unit is not enough as a result of large amount of hot water use, the heat pump starts operating as appropriate to perform additional heating-up. Further improvement of efficiency can be expected from the advancement of control technologies such as timing of heating-up in daytime and nighttime and setting of the end of heat-up.

(2) Specific target standard values

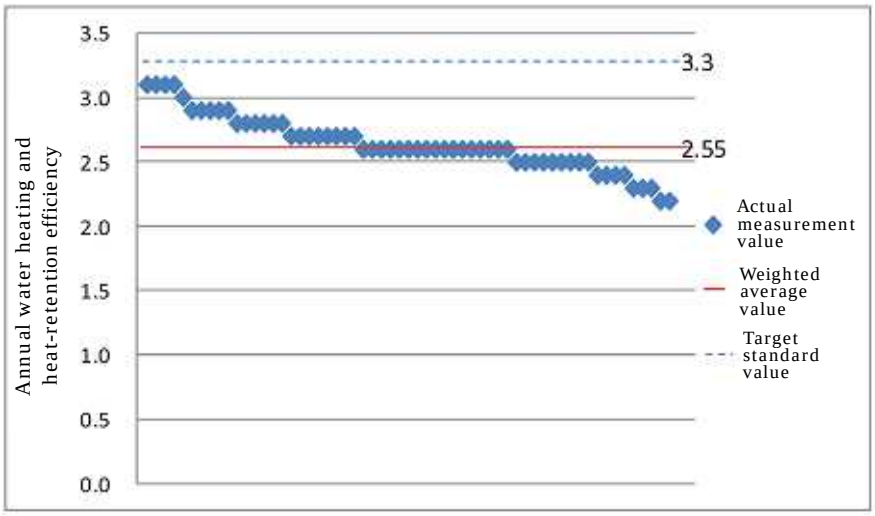
According to the categories of heat pump water heaters, the Top Runner values were obtained from actual measured values (FY2009) and estimated values of annual water heating and heat-retention efficiency (in case of products with a bathwater heat-retention function) and annual water heating efficiency (products without a bathwater heat-retention function), then the target standard values were set according to the status of each category and taking into account the improvement expected to be made by the target fiscal year. When doing this, products were divided into 4 groups based on the ideas described in (A) to (D) below. Specific target standard values are as shown in Table 4-1 and Table 4-2.

(A) A major group corresponding to approximately 90% of the total number of products shipped

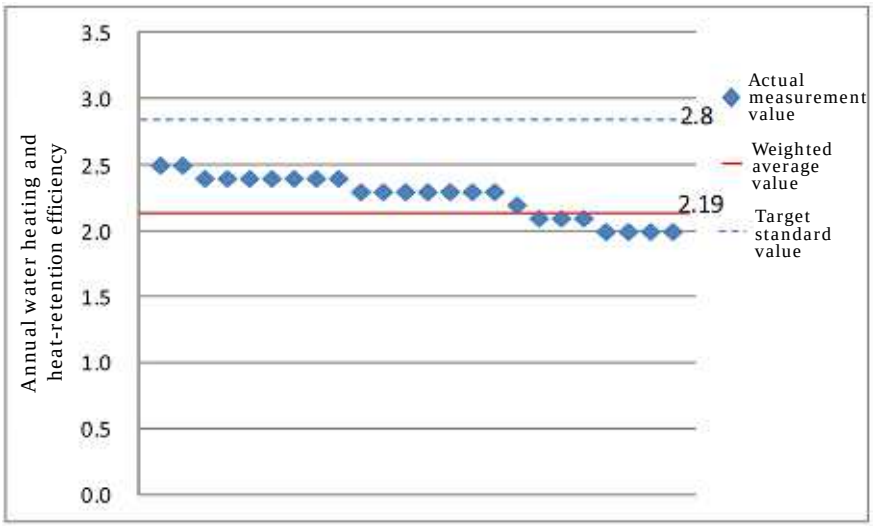
Category	Hot water storage capacity	Intended area	Heat-retention function	Number of hot water storage tanks	Shipment ratio
17	320 L or above, below 550 L	Normal area	With	Single	68.6%
18				Multiple	12.9%
19			Without	Single	8.7%

For heat pump water heaters belonging to this major group, elemental technologies have actively been introduced. Based on this fact, Top Runner values are obtained from the actual measurement values, and as much as 3 to 12% of improvement from the Top Runner values by the target fiscal year is determined. Besides 1% improvement at the heat pump side, the improvement rate may account for (a) 0 to 2% due to the enhancement of thermal insulation materials, (b) 0 to 2% due to the installation of a circuit for taking out medium temperature water and (c) 2 to 7% due to the betterment of heating-up control at the hot water storage tank and supply circuit side.

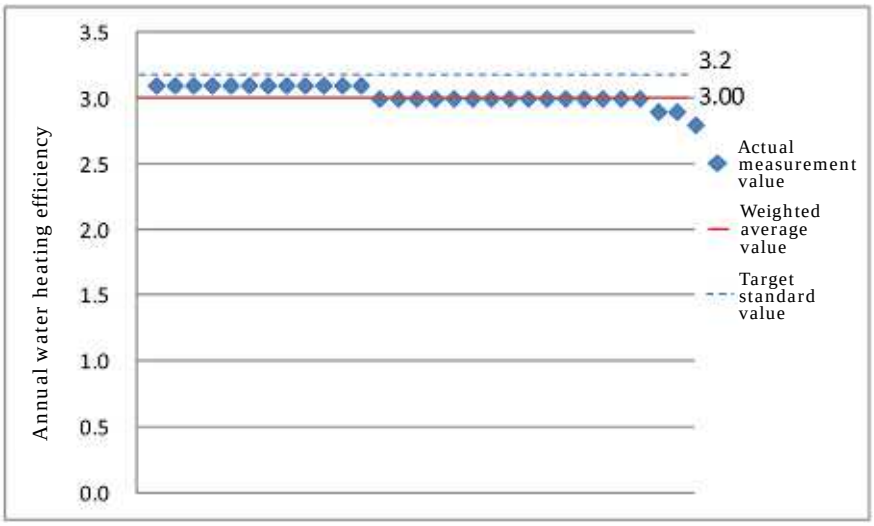
[Category 17]



[Category 18]



[Category 19]

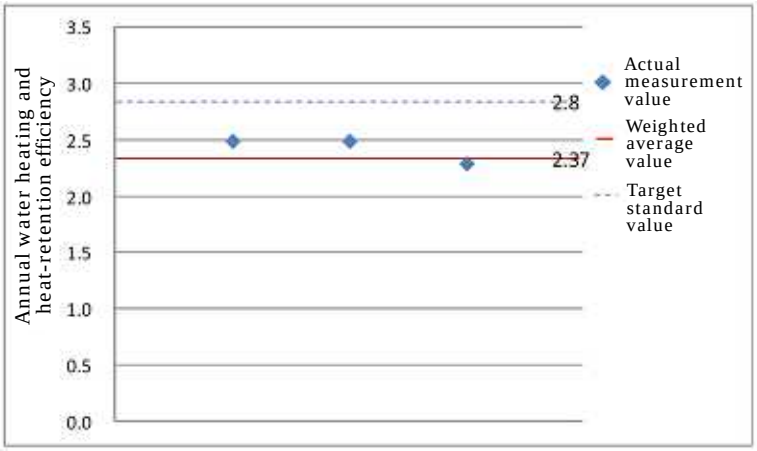


(B) A group whose shipment ratio in the total shipment is currently as low as approximately 3.5% but, as being close to the (A) group, expected to increase due to an anticipated enhancement of product line-up hereafter

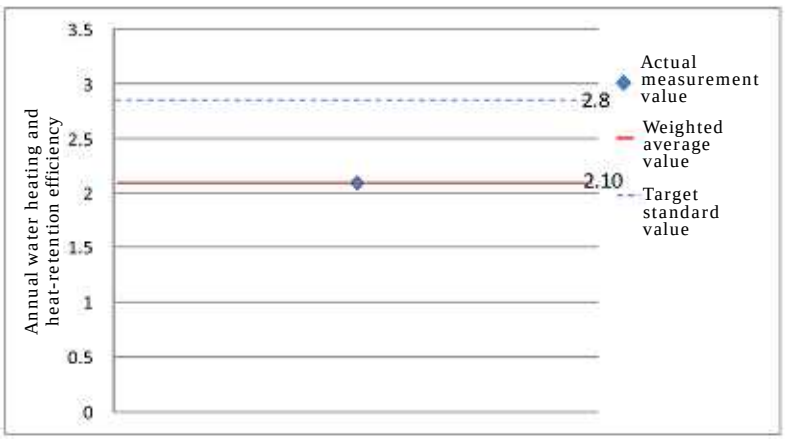
Category	Hot water storage capacity	Intended area	Heat-retention function	Number of hot water storage tanks	Shipment ratio
9	240 L or above, below 320 L	Normal area	With	Single	3.5%
10				Multiple	
11			Without	Single	
25	550 L or above		With	Single	
27			Without	Single	

Product development or model-change has not actively been implemented so far for products in this category, since they are marginal products of the main product group. Based on this fact, Top Runner values are obtained from actual measurement values, and as much as 4 to 33% of improvement from the Top Runner values by the target fiscal year is determined. Besides 0 to 5% improvement at the heat pump side, the improvement rate may account for (a) 1% due to the enhancement of thermal insulation materials, (b) 0 to 3% due to the installation of a circuit for taking out medium temperature water and (c) 2 to 30% due to the betterment of heating-up control at the hot water storage tank and supply circuit side.

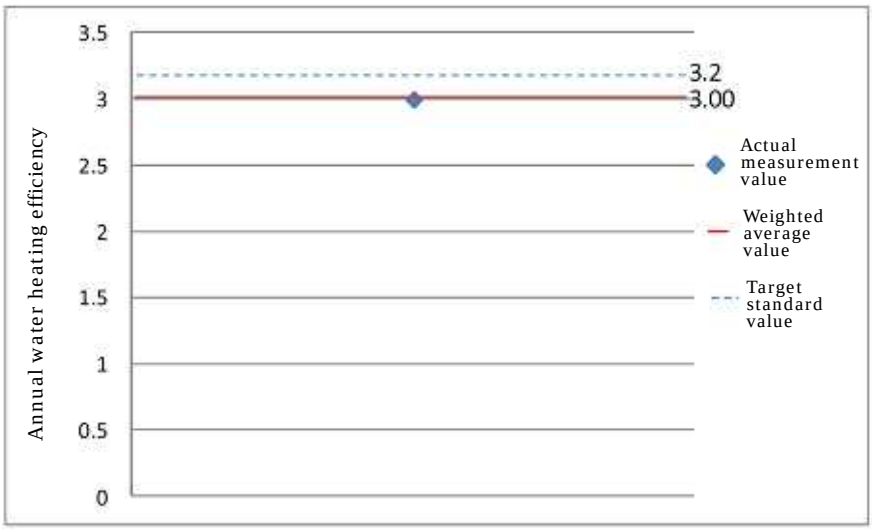
[Category 9]



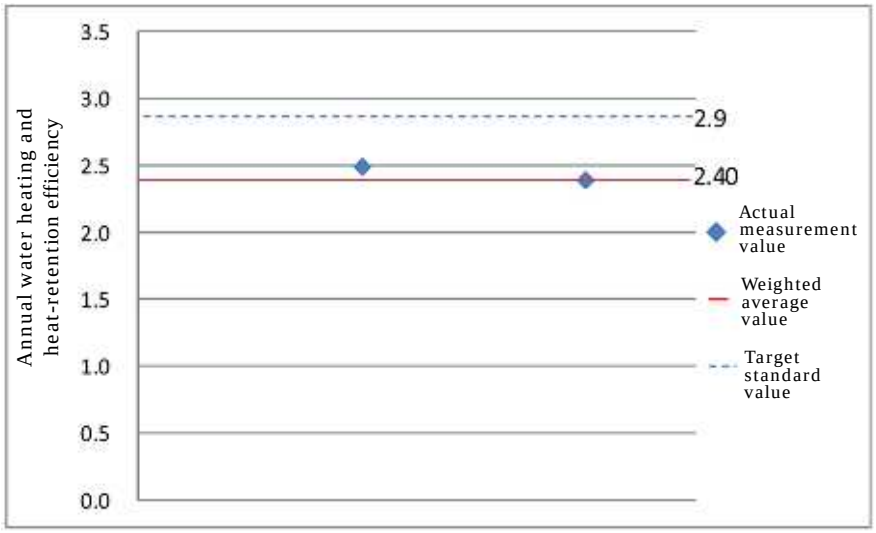
[Category 10]



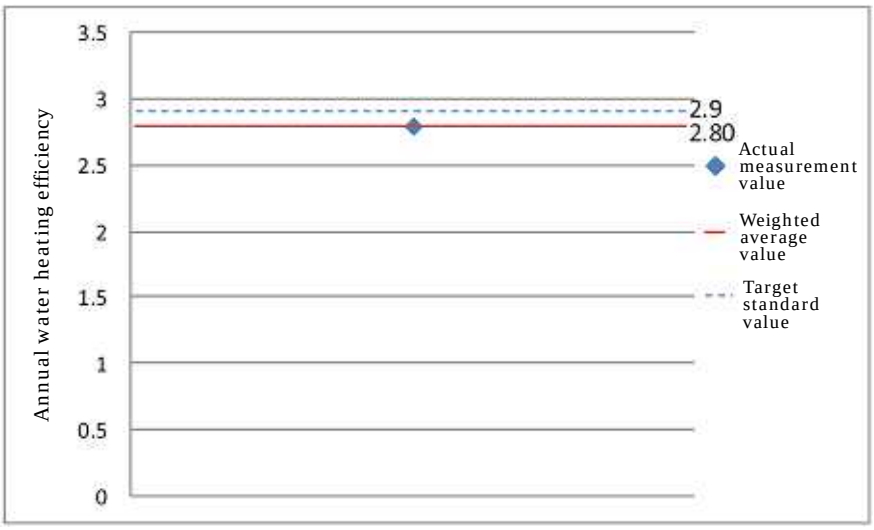
[Category 11]



[Category 25]



[Category 27]

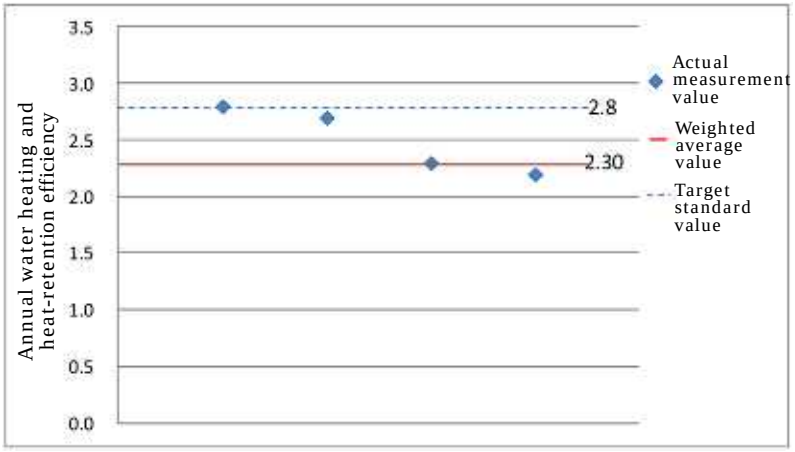


(C) A group of products made for standard households but with small hot water storage capacity, products made for households with fewer family members and products made for use in cold areas.

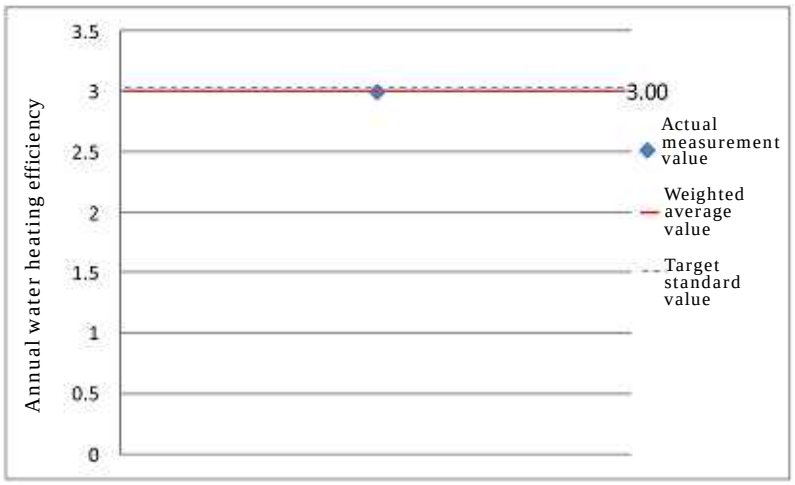
Category	Assumed household	Hot water storage capacity	Intended area	Heat-retention function	Number of hot water storage tanks	Shipment ratio
1	Standard	Below 240 L	Normal area	With	Single	1.0%
3				Without	Single	
33	Fewer family members	–		With	–	
21	Standard	320 L or above, below 550 L	Cold area	With	Single	5.3%
23				Without	Single	

The shipment ratio of products for standard households but with small hot water storage capacity due to restrictions on installation places and of products for households with fewer family members is as low as approximately 1% in the total shipment. Meanwhile, the shipment ratio of products which are the only ones available in the market among those intended for cold area is also as low as approximately 5.3% in the total shipment. Therefore, the Top Runner values of actual measurement values are directly set as the Top Runner values in the target fiscal year for these products.

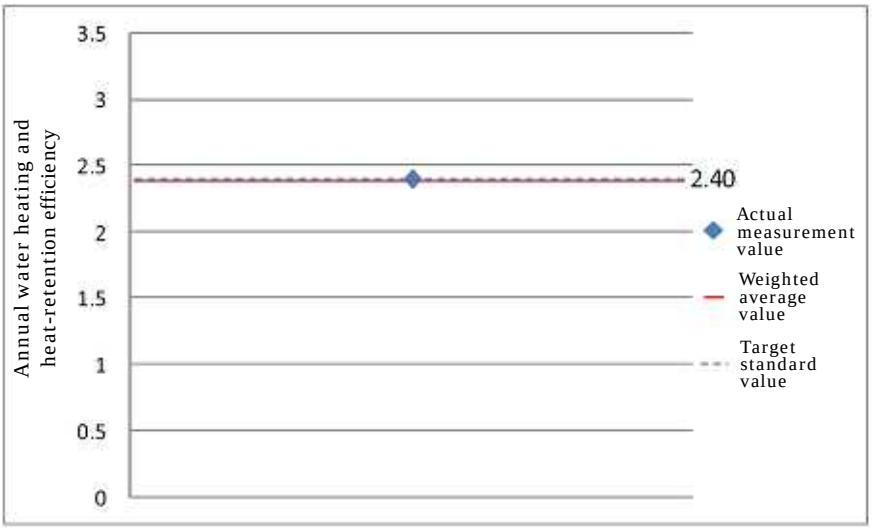
[Category 1]



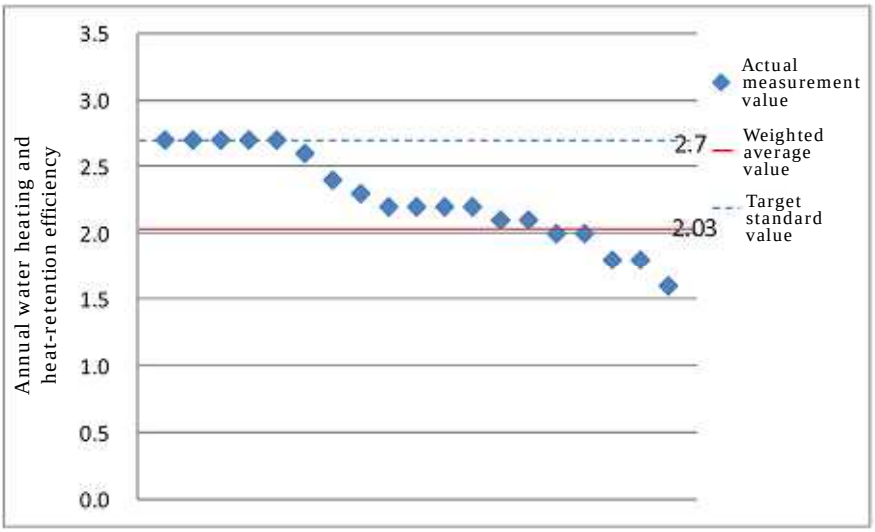
[Category 3]



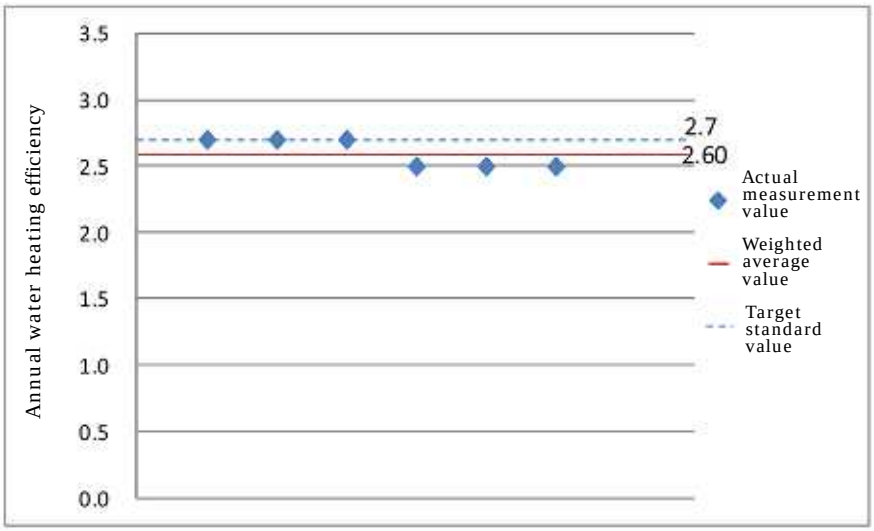
[Category 33]



[Category 21]



[Category 23]



(D) A group in which products do not exist in data of the reference fiscal year (FY2009)

Since actual measurement values of this group of products are not available, the Top Runner values in the target fiscal year were estimated using the ratios in other categories (See Table 4-1). When doing this, fraction numbers were rounded up in order to further promote energy saving. Details are as per (1) to (7) below, which are corresponding to the numbers listed in Table 4-1.

(1) Estimation method of products for normal area, for standard household and with multiple tanks:
The ratio of target standard values (3.3:2.8) of (a) single-tank type and (b) multi-tank type of products whose capacity is 320 L or above and below 550 L and which are equipped with a heat-retention function is applied to the relation of the target standard value of single-tank products to the value of multi-tank products sharing the same capacity category and the same heat-retention function category.
* Category 2, 4, 12, 20, 26 and 28 fall under the case of (1).

(2) Estimation method of products for cold area, for standard household, with a heat-retention function and with single tank:
The ratio of target standard values (3.3:2.7) of products (a) intended for normal area and (d) intended for cold area whose capacity is 320 L or above and below 550 L is applied to the relation of the target standard value of products intended for normal area to the value of products intended for cold area sharing the same capacity category.
* Category 5, 13 and 29 fall under the case of (2).

(3) Estimation method of products for cold area, for standard household, without a heat-retention function and with single tank:
The ratio of target standard values (3.2:2.7) of products (c) intended for normal area and (e) intended for cold area whose capacity is 320 L or above and below 550 L is applied to the relation of the target standard value of products intended for normal area to the value of products intended for cold area sharing to the same capacity category.
* Category 7, 15 and 31 fall under the case of (3).

(4) Estimation method of products for cold area, for standard household and with multiple tanks:
The ratio of target standard values (3.3:2.8) of (a) single-tank type and (b) multi-tank type of products intended for normal area whose capacity is 320 L or above and below 550 L and which are equipped with a heat-retention function is applied to the relation of the target standard value of single-tank products intended for cold area to the value of multi-tank products intended for cold area sharing the same capacity category and the same heat-retention function category.
* Category 6, 8, 14, 16, 22, 24, 30 and 32 fall under the case of (4).

(5) Estimation method of products for normal area, for household with fewer family members and without a heat-retention function:
The ratio of target standard values (2.8:3.2) of single-tank products (f) with a heat-retention function and (g) without a heat-retention function which are for standard household and whose capacity is 240 L or above and below 320 L is applied to the relation of the target standard value of products with a heat-retention function to the value of products without the function sharing the same intended area category and the same assumed household category.
* Category 34 falls under the case of (5).

(6) Estimation method of products intended for cold area, for household with fewer family members and with a heat-retention function:

The ratio of target standard values (3.3:2.7) of single-tank products (a) intended for normal area and (d) intended for cold area which are for standard household and equipped with a heat-retention function and whose capacity is 320 L or above and below 550 L is applied to the relation of the target standard value of products intended for normal area, for household with fewer family members and with a heat-retention function to the value of products intended for cold area sharing the same assumed household category and the same heat-retention function category.

* Category 35 falls under the case of (6).

(7) Estimation method of products intended for cold area, for household with fewer family members and without a heat-retention function:

The ratio of target standard values (3.2:2.7) of single-tank products (c) intended for normal area and (e) intended for cold area which are for standard household and equipped with a heat-retention function and whose capacity is 320 L or above and below 550 L is applied to the relation of the target standard value of products intended for normal area, for households with fewer family members and without a heat-retention function to the value of products intended for cold area sharing the same assumed household category and the same heat-retention function category.

* Category 36 falls under the case of (7).

Table 4-1 Target Standard Values for Heat Pump Water Heaters

[Products intended for normal area]

Intended area	Assumed household	Heat-retention function	Number of tanks	Below 240 L	240 L or above, below 320 L	320 L or above, below 550 L	550 L or above
Normal area	Standard	With	Single	Category 1 (C) 2.8	Category 9 (B) 2.8 (f)	Category 17 (A) 3.3 (a)	Category 25 (B) 2.9
			Multiple	Category 2 (D) (1) 2.4	Category 10 (B) 2.8	Category 18 (A) 2.8 (b)	Category 26 (D) (1) 2.5
		Without	Single	Category 3 (C) 3.0	Category 11 (B) 3.2 (g)	Category 19 (A) 3.2 (c)	Category 27 (B) 2.9
			Multiple	Category 4 (D) (1) 2.6	Category 12 (D) (1) 2.8	Category 20 (D) (1) 2.8	Category 28 (D) (1) 2.5
	Fewer family members	With	—	Category 33 (C) 2.4			
		Without	—	Category 34 (D) (5) 2.8			

[Products intended for cold area]

Intended area	Assumed household	Heat-retention function	Number of tanks	Below 240 L	240 L or above, below 320 L	320 L or above, below 550 L	550 L or above
Cold area	Standard	With	Single	Category 5 (D) (2) 2.3	Category 13 (D) (2) 2.3	Category 21 (C) 2.7 (d)	Category 29 (D) (2) 2.4
			Multiple	Category 6 (D) (4) 2.0	Category 14 (D) (4) 2.0	Category 22 (D) (4) 2.3	Category 30 (D) (4) 2.1
		Without	Single	Category 7 (D) (3) 2.6	Category 15 (D) (3) 2.7	Category 23 (C) 2.7 (e)	Category 31 (D) (3) 2.5
			Multiple	Category 8 (D) (4) 2.3	Category 16 (D) (4) 2.3	Category 24 (D) (4) 2.3	Category 32 (D) (4) 2.2
	Fewer family members	With	—	Category 35 (D) (6) 2.0			
		Without	—	Category 36 (D) (7) 2.4			

Table 4-2 Target Standard Values for Heat Pump Water Heaters per Category

Category	Assumed household	Hot water storage capacity	Intended area	Heat-Retention function	Number of hot water storage tanks	[Reference fiscal year] Weighted average values	[Reference fiscal year] Top Runner values	[Target fiscal year] Target standard values	Improvement from Top Runner value [%]	Improvement from weighted average values [%]
1	Standard	Below 240 L	Normal area	With	Single	2.30	2.8		–	22
2					Multiple	–	–	2.4	–	–
3				Without	Single	3.00	3.0		–	–
4					Multiple	–	–	2.6	–	–
5			Cold area	With	Single	–	–	2.3	–	–
6					Multiple	–	–	2.0	–	–
7				Without	Single	–	–	2.6	–	–
8					Multiple	–	–	2.3	–	–
9		240 L or above, below 320 L	Normal area	With	Single	2.37	2.5	2.8	12	18
10					Multiple	2.10	2.1	2.8	33	33
11				Without	Single	3.00	3.0	3.2	7	7
12					Multiple	–	–	2.8	–	–
13			Cold area	With	Single	–	–	2.3	–	–
14					Multiple	–	–	2.0	–	–
15				Without	Single	–	–	2.7	–	–
16					Multiple	–	–	2.3	–	–
17		320 L or above, below 550 L	Normal area	With	Single	2.55	3.1	3.3	6	29
18					Multiple	2.19	2.5	2.8	12	28
19				Without	Single	3.00	3.1	3.2	3	7
20					Multiple	–	–	2.8	–	–
21			Cold area	With	Single	2.03	2.7		–	33
22					Multiple	–	–	2.3	–	–
23				Without	Single	2.60	2.7		–	4
24					Multiple	–	–	2.3	–	–
25		550 L or above	Normal area	With	Single	2.40	2.5	2.9	16	21
26					Multiple	–	–	2.5	–	–
27				Without	Single	2.80	2.8	2.9	4	4
28					Multiple	–	–	2.5	–	–
29			Cold area	With	Single	–	–	2.4	–	–
30					Multiple	–	–	2.1	–	–

31				Without	Single	–	–	2.5	–	–
32					Multiple	–	–	2.2	–	–
33	Fewer family members	–	Normal area	With	–	2.40	2.4		–	–
34				Without				2.8	–	–
35			Cold area	With				2.0	–	–
36				Without				2.4	–	–
Total						2.49	2.88	3.16	10	27

Attachment 5

Energy Consumption Efficiency of Heat Pump Water Heaters and the Measuring Method

1. Basic idea

For the measurement of energy consumption efficiency of heat pump water heaters, the measuring method based on actual usage, which is stipulated in JIS C 9220 “Residential Heat Pump Water Heaters” (hereinafter referred to as JIS C 9220) of year 2011, shall be adopted.

2. Specific energy consumption efficiency and the measuring method

(1) Energy consumption efficiency

Energy consumption efficiency of a heat pump water heater is the ratio of heat quantity transferred to circulating hot water to electric power consumption per time unit when the heat pump is operating. It is expressed as “annual water heating and heat-retention efficiency” in case of heat pump water heaters with a bath water heat-retention function and as “annual water heating efficiency” in case of those without said function, both of which shall be measured by the method stipulated by JIS C 9220 (see Attachment) and calculated by the following formulae.

<Those with a bath water heat-retention function>

$$\text{Annual water heating and heat-retention efficiency} = \frac{\text{Heat quantity acquired by hot water used in a year} + \text{Heat quantity acquired by bathtub water for heat-retention (MJ)}}{\text{Annual energy consumption (kWh)} \times 3.6}$$

<Those without a bath water heat-retention function>

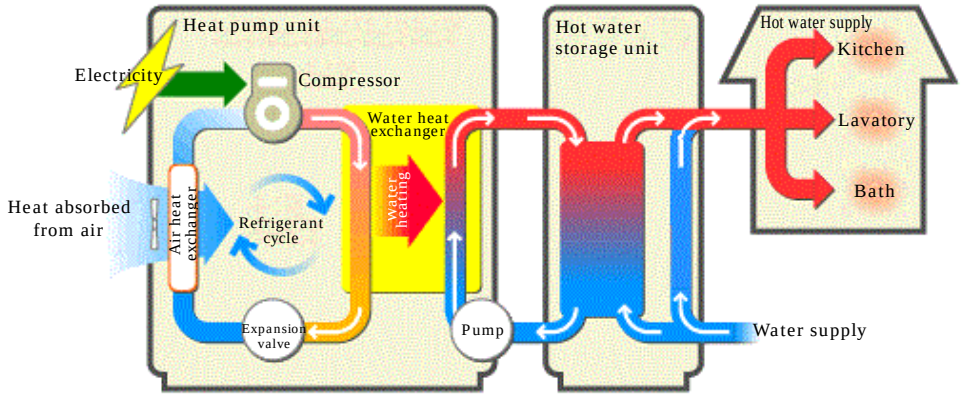
$$\text{Annual water heating efficiency} = \frac{\text{Heat quantity acquired by hot water used in a year (MJ)}}{\text{Annual energy consumption (kWh)} \times 3.6}$$

Attachment

Methods for Measurement and Calculation of Annual Water Heating and Heat-retention Efficiency (for Products with a Bathwater Heat-retention Function)

1. Procedures for measurement and calculation of annual water heating and heat-retention efficiency

   A residential heat pump water heater is composed of a "heat pump unit" and a "hot water storage unit".



Composition of Residential Heat Pump Water Heater

- Specific procedures for measurement and calculation of energy consumption efficiency are as follows.

[Procedure (1)] Calculation of "water heating and heat-retention mode efficiency" of a system as a whole

- The measurement is performed in "water heating and heat-retention mode (under the winter condition)" according to an actual usage.

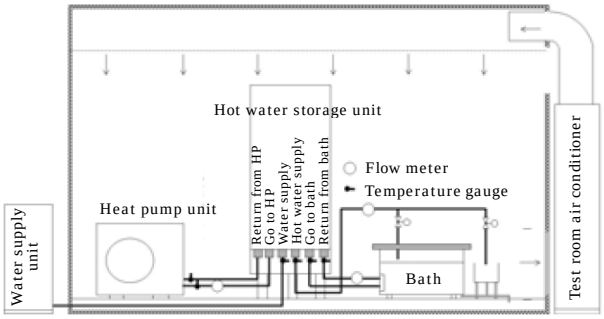
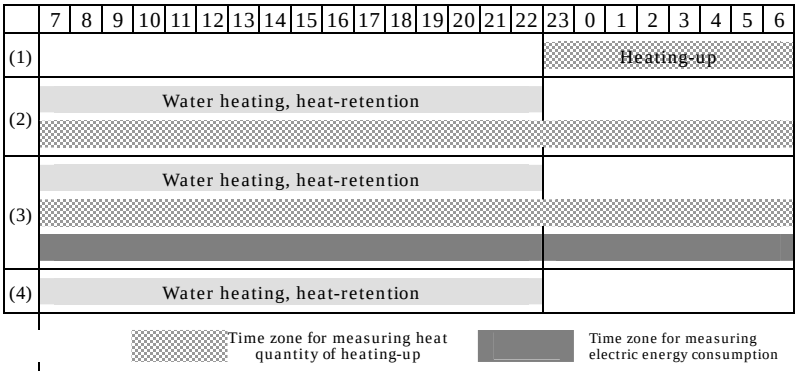
[Procedure (2)] Calculation of "heat pump unit efficiency"

- The measurement is performed under 6 temperature conditions (i.e. standard heating conditions (middle season, summer and winter), high temperature heating conditions (winter and frosting season) and water heating mode heating condition).
  * For products intended for cold area, an additional measurement shall be performed under a high temperature heating condition for winter season in cold area.

[Procedure (3)] Calculation of "annual water heating and heat-retention efficiency"

(1) A factor is obtained from "water heating and heat-retention mode efficiency" and "heat pump unit efficiency" under the winter condition. With the factor, "water heating and heat-retention mode efficiency" under each outside temperature is calculated.
(2) "Annual heat quantity of water heating and heat-retention" is calculated from the number of days when applicable outside temperature occurs and the in-coming water temperature.
(3) "Energy consumption" at each outside temperature is obtained from "heat quantity of water heating and heat-retention mode" and the "water heating and heat-retention mode efficiency" of each outside temperature, and they are summed up to obtain "annual energy consumption".
(4) "Annual water heating and heat-retention efficiency" is calculated from the "annual heat quantity of water heating and heat-retention" and the "annual energy consumption".

2. Outline of methods for measurement and calculation of annual water heating and heat-retention efficiency

Items		Outline - In the case of products with a bathwater heat-retention function -
Procedure (1) Calculation of "water heating and heat-retention mode efficiency" of a system as a whole	Temperature condition	Air temperature: Dry bulb 7.0±1°C, wet bulb 6.0±0.5°C Water temperature: Water supply temperature 9.0±2.0°C
	Test instrument	Test facility, sample product for test and, placement of measuring instruments for a heat pump water heater (Example)  Measurement instruments a) Temperature gauges to measure temperatures of water supply and hot water supply, and a flow meter to measure the volume of hot water supply b) Temperature gauges to measure temperatures of hot-water going-to-bath and returning-from-bath, and a flow meter to measure the volume of hot water returning from bath. c) An integrating wattmeter to measure electric power consumption of a residential heat pump water heater d) Temperature gauges to measure temperatures of water going to and returning from the heat pump unit, and a flow meter to measure the volume of water going to the heat pump unit. e) A thermocouple to monitor the heat quantity of hot water remaining in the hot water storage tank.
	Operational state	Test shall be conducted by operating a residential heat pump water heater at the rated frequency and the rated voltage (the tolerance is within ±2% for each rating). A residential heat pump water heater shall be operated with an as-shipped operation setting. However, in case of a product equipped with a learning control function, it shall be operated with an as-shipped operation setting until the operation is stabilized in a water heating and heat-retention mode. If remaining hot water amount after the operation is stabilized is below 100 L at 40°C, the operation setting must be changed so that the remaining hot water amount becomes 100 L or above at 40°C. How to set this operation setting for test shall be documented in a technical data. Heating-up temperature of the operation setting for test must be the same or above the heating-up temperature when the product is in a stable state after being operated in the water heating and heat-retention mode with the as-shipped operation setting.
	Heat quantity of water heating and heat-retention	Water heating and heat-retention mode: "Standard Usage Mode for Bathwater Heating of Bath Furnace with Hot Water Supply Function" of JIS S 2072 is adopted (Attachment 1). * To enhance the accuracy of measuring heat quantity of water heating, a usage mode which summarizes successive operations having the same intended usage is prepared (Attachment 2). (As for a water heating mode, TS S 0003 "Standard Usage Mode of Water Heating Appliances used for Kitchens, Lavatories, Showers and Baths" is adopted.)
	Test procedures	Water heating performance test is conducted according to the following schedule, and then the heat quantity of water heating and heat-retention and the electric energy consumption on the third day are measured. The heat quantity of water heating on each day must be within the range of ±5%, and the heat quantity of heating-up on the second and third days must be within the range of ±5%. <Presumed time> 

Items		Outline - In the case of products with a bathwater heat-retention function -
Procedure (1) Calculation of "water heating and heat-retention mode efficiency"	Calculation formula	<u>Water heating and heat-retention mode efficiency is calculated by the following formula.</u> Water heating and heat-retention mode efficiency $C_{MW1} = \frac{Q_{MW1}}{P_{MW1} \times 3.6}$ Here: C_{MW1}: Water heating and heat-retention mode efficiency Q_{MW1}: Heat quantity of water heating and heat-retention mode (MJ) ← Total of water heating's heat quantity and heat-retention's heat quantity of one day P_{MW1}: Energy consumption in water heating and heat-retention mode (kWh) ← Energy consumption of one day when operating in water heating and heat-retention mode 3.6: Factor to convert kWh to MJ Heat quantity of water heating $Q = \sum_{j=t_s}^{t_e} \left\{ (T_m - T_i) \times q_m \times \rho \times c_p \times t_m \right\}$ Here: Q: Heat quantity of each water heating mode (kJ) j: Section numbered for each measurement interval T_m: Hot water supply temperature (°C) t_s: Time when hot water supply starts t_e: Time when hot water supply ends T_i: Water supply temperature when simultaneously measuring each hot water supply temperature (°C) ρ: Water density at each hot water supply temperature (kg/L).....(from Table A.4) c_p: Average specific heat of water 4.1796 (kJ/kg･°C).....(constant value) q_m: Flow rate in measurement interval (L/min) t_m: Measurement interval (min) Heat quantity of heat-retention $Q_k = \sum_{j=t_s}^{t_e} \left\{ (T_{ok} - T_{ik}) \times q_k \times \rho \times c_p \times t_k \right\}$ Here: Q_k: Heat quantity of each heat-retention mode (kJ) j: Section numbered for each measurement interval T_{oK}: Temperature of water going to bath (°C) t_s: Time when valid heat quantity of water heating starts t_e: Time when hot water supply ends T_{ik}: Temperature of hot water returning from bath when simultaneously measuring temperature of hot water going to bath (°C) ρ: Water density at temperature of water going to bath (kg/L)..... (from Table A.4) c_p: Average specific heat of water 4.1796 (kJ/kg･°C)..... (constant value) q_k: Flow rate in measurement interval (L/min) t_m: Measurement interval (min) Accumulation shall be made as far as the condition of $T_{oK} > T_{ik}$ is right.

Items	Outline - In the case of products with a bathwater heat-retention function -

Procedure (2) Calculation of "heat pump unit efficiency"

Temperature conditions

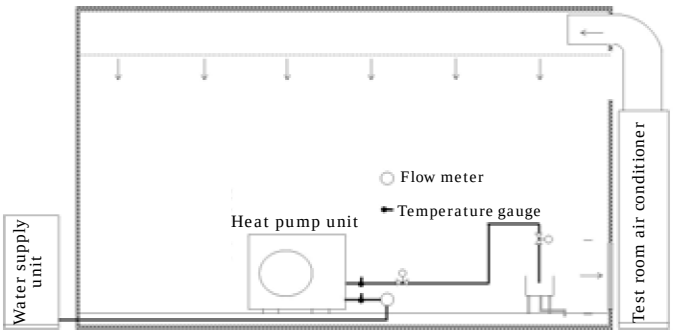
Unit: °C

Conditions	Temperature setting of going-out hot water	Inlet air temperature		Water temperature	Procedure (3)
		Dry bulb temperature	Wet bulb temperature	In-coming water temperature	COP performance line No.
Standard heating condition for middle season	Standard heating-up temperature	16	12	17	(2)
Standard heating condition for summer	Standard heating-up temperature	25	21	24	(3)
Standard heating condition for winter	Standard heating-up temperature	7	6	9	(1)
High temperature heating condition for winter	High heating-up temperature for winter	7	6	9	(4)
High temperature heating condition for frosting season	High heating-up temperature for frosting season	2	1	5	(5)
High temperature heating condition for winter in cold area	High heating-up temperature for winter in cold area	–7	–8	5	(6)
Water heating mode heating condition	Heating-up temperature during the water heating mode performance test	7	6	9	(8)

* Performance test under the high temperature heating condition for winter in cold area shall be performed for products intended for cold area.

Test instrument

Test facility and placement of sample product for test (Example)



Test procedure

a) Measurement under steady condition
Once the test condition reaches a steady state, allow the unit to operate for at least one hour, and then measurements shall be taken 7 times at 5 minute interval.

b) Measurement under transient condition
Heating capacity test of heat pump while in a state accompanying defrosting.

Calculation formula

"Heat pump unit efficiency" under each condition is obtained from dividing heating capacity, as calculated per the following formula, by electric power consumption in a steady state. Thus, the heating capacity is calculated by the following formula, using the average of measured values.

$$\Phi = (T_2 - T_1) \cdot qr \cdot c_p$$

Here:

Φ: Total heating capacity of a heat pump, which is calculated from the heat exchange amount of a heat exchanger of the use side.

T_1: Inlet water temperature of a heat exchanger of the use side (°C)

T_2: Outlet water temperature of a heat exchanger of the use side (°C)

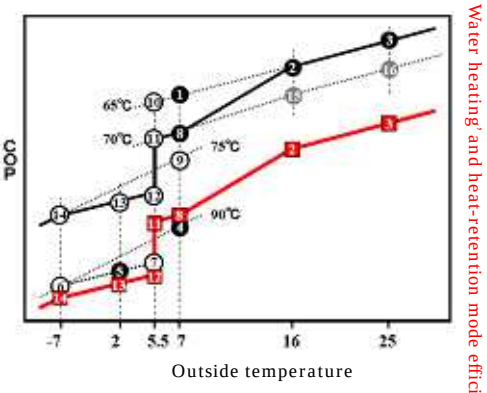
c_p: Specific heat of water (J/kg°C)

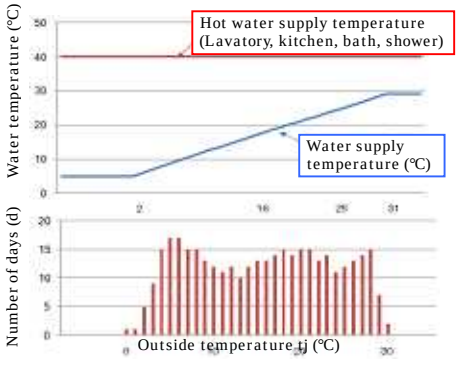
qr: Mass flow rate of a heat exchanger of the use side (kg/s)

→Water heating and heat-retention mode energy consumption efficiency, $C_{HMT1,}$ is "heat pump unit efficiency" at the heating-up temperature of water heating mode performance test.

Items		Outline - In the case of products with a bathwater heat-retention function -
Procedure (3) Calculation of "annual water heating and heat-retention efficiency"	Water heating and heat-retention efficiency factor of a heat pump	Water heating and heat-retention efficiency factor of a heat pump, F_{HM1}, is the ratio of water heating and heat-retention mode efficiency, C_{MW1}, obtained in the procedure (1) to water heating and heat-retention mode energy consumption efficiency, C_{HMT1}, obtained in the procedure (2). The factor is calculated by the following formula. $$F_{HM1} = \frac{C_{MW1}}{C_{HMT1}}$$ Here: C_{HMT1}: Water heating and heat-retention mode energy consumption efficiency ← From the procedure (2) C_{MW1}: Water heating and heat-retention mode efficiency ← From the procedure (1)
	Temperature condition	Number of days when each of listed average outside nighttime temperature occurs in a year.
	Calculation formula	I) From the heat pump unit efficiency under each condition (COP) obtained in the procedure (2), heat pump unit efficiency (COP) per outside temperature and per going-out hot water temperature is calculated (Right figure: COP performance line). II) From the water heating and heat-retention efficiency factor of a heat pump, F_{HM1}, and the heat pump unit efficiency per outside temperature and going-out hot water temperature, water heating and heat-retention mode efficiency, C_{M1} (tj), per outside temperature is calculated (Right figure: water heating and heat-retention mode efficiency performance line). III) Annual heat quantity of water heating and heat-retention, QMA1, is calculated by multiplying the heat quantity of water heating and heat-retention when outside temperature is tj, QM1 (tj), by the number of days when outside temperature is tj, then by totaling them. $$Q_{MA1} = \sum_{j=1}^{43} \{Q_{M1}(tj) \cdot dj\}$$ IV) Energy consumption when outside temperature is tj, P_{M1} (tj), is calculated by dividing the heat quantity of water heating and heat-retention when outside temperature is tj, Q_{M1} (tj), by the water heating and heat-retention mode efficiency, C_{M1} (tj). Then, annual water heating and heat-retention mode energy consumption, P_{MA1}, is calculated by multiplying the energy consumption calculated above by the number of days when outside temperature is tj, then by totaling them. $$P_{MA1} = \sum_{j=1}^{43} \left\{ \frac{Q_{M1}(tj)}{C_{M1}(tj) \times 3.6} \times dj \right\}$$ V) Annual water heating and heat-retention efficiency, C_{MA1}, is calculated by the following formula. $$C_{MA1} = \frac{Q_{MA1}}{P_{MA1} \times 3.6}$$ Here: C_{MA1}: Annual water heating and heat-retention efficiency when performing water heating and heat-retention in water heating and heat-retention mode Q_{MA1}: Annual heat quantity of water heating and heat-retention mode (MJ) P_{MA1}: Annual water heating and heat-retention mode energy consumption (kWh) 3.6: Factor to convert kWh to MJ

Temperature category *j*	Outside temperature *tj* ℃	Number of days *dj* d	Temperature category *j*	Outside temperature *tj* ℃	Number of days *dj* d	Temperature category *j*	Outside temperature *tj* ℃	Number of days *dj* d
1	–10	0	16	5	17	31	20	15
2	–9	0	17	6	17	32	21	15
3	–8	0	18	7	15	33	22	13
4	–7	0	19	8	15	34	23	14
5	–6	0	20	9	13	35	24	11
6	–5	0	21	10	12	36	25	12
7	–4	0	22	11	11	37	26	13
8	–3	0	23	12	12	38	27	14
9	–2	0	24	13	10	39	28	15
10	–1	0	25	14	12	40	29	7
11	0	1	26	15	13	41	30	2
12	1	1	27	16	13	42	31	0
13	2	5	28	17	14	43	32	0
14	3	9	29	18	15	–	–	–
15	4	15	30	19	14	Total		365





Items		Outline - In the case of products with a bathwater heat-retention function -
Others	Products for households with fewer family members	Evaluation shall be made after replacing the water heating and heat-retention loads by the ones according to water heating and heat-retention mode for household with fewer family members (Stipulation). * A usage mode which lists operations in water heating and heat-retention mode for households with fewer family members as well as a usage mode which summarizes successive operations having the same intended usage listed in the aforementioned mode are prepared (Attachment 3).
	Products intended for cold area	Annual water heating and heat-retention efficiency is calculated by using the following table for outside temperature, water supply temperature and number of days when each outside temperature occurs. Annual water heating and heat-retention efficiency for normal area shall also be indicated for reference.

II Area (Morioka)

Temperature category *j*	Outside temperature *tj* ℃	Number of days *dj* d	Temperature category *j*	Outside temperature *tj* ℃	Number of days *dj* d	Temperature category *j*	Outside temperature *tj* ℃	Number of days *dj* d
1	–10	0	16	5	10	31	20	11
2	–9	1	17	6	11	32	21	9
3	–8	2	18	7	11	33	22	9
4	–7	3	19	8	9	34	23	9
5	–6	5	20	9	10	35	24	6
6	–5	8	21	10	9	36	25	4
7	–4	11	22	11	10	37	26	1
8	–3	13	23	12	11	38	27	0
9	–2	15	24	13	11	39	28	0
10	–1	16	25	14	12	40	29	0
11	0	20	26	15	13	41	30	0
12	1	16	27	16	15	42	31	0
13	2	13	28	17	15	43	32	0
14	3	11	29	18	13	–	–	–
15	4	9	30	19	13	Total		365

To calculate annual water heating and heat-retention efficiency of products intended for cold area, heat pump unit efficiency of product under the following condition shall be actually measured.

Unit: °C

Condition	Temperature setting of going-out hot water	Inlet air temperature		Water temperature
		Dry bulb temperature	Wet bulb temperature	In-coming water temperature
High temperature heating condition for winter in cold area	High heating-up temperature in cold area	–7	–8	5

Attachment 1

Water heating and heat-retention mode

Heat quantities are those in the winter condition.

No.	Usage	Start time	Heat quantity of hot water heating MJ	Heat quantity of heat-retention MJ	Flow rate L/min	Hot water supply amount L
1	Lavatory	7:00:00	1.286	–	5	10.00
2	Lavatory	7:02:30	0.107	–	5	0.83
3	Lavatory	7:03:10	0.107	–	5	0.83
4	Lavatory	7:04:20	0.107	–	5	0.83
5	Lavatory	7:05:00	0.107	–	5	0.83
6	Kitchen	8:15:00	0.643	–	5	5.00
7	Kitchen	8:16:30	0.107	–	5	0.83
8	Kitchen	8:17:10	0.107	–	5	0.83
9	Kitchen	8:27:20	3.214	–	5	25.00
10	Kitchen	8:34:20	0.321	–	5	2.50
11	Kitchen	13:00:00	0.643	–	5	5.00
12	Kitchen	13:01:30	0.107	–	5	0.83
13	Kitchen	13:02:10	0.107	–	5	0.83
14	Kitchen	13:07:20	1.286	–	5	10.00
15	Kitchen	13:10:20	0.321	–	5	2.50
16	Kitchen	18:15:00	0.643	–	5	5.00
17	Kitchen	18:16:30	0.107	–	5	0.83
18	Kitchen	18:18:40	0.643	–	5	5.00
19	Kitchen	18:24:40	0.643	–	5	5.00
20	Kitchen	18:26:10	0.107	–	5	0.83
21	Kitchen	18:26:50	0.107	–	5	0.83
22	Kitchen	18:27:30	0.107	–	5	0.83
23	Kitchen	18:32:40	0.321	–	5	2.50
24	Kitchen	18:33:40	0.107	–	5	0.83
25	Kitchen	18:34:20	0.107	–	5	0.83
26	Bath	19:40:00	23.143	–	10-15	180.00
27	Kitchen	20:00:00	1.286	–	5	10.00
28	Kitchen	20:02:30	0.321	–	5	2.50
29	Shower	20:08:00	2.571	–	10	20.00
30	Kitchen	20:12:00	0.321	–	5	2.50
31	Kitchen	20:13:00	0.107	–	5	0.83
32	Kitchen	20:18:10	0.321	–	5	2.50
33	Kitchen	20:19:10	0.107	–	5	0.83
34	Kitchen	20:19:50	0.107	–	5	0.83
35	Heat-retention	20:27:00	–	1.020	–	–
36	Shower	20:30:00	6.428	–	10	50.00
37	Kitchen	20:36:00	0.107	–	5	0.83
38	Kitchen	20:36:40	0.107	–	5	0.83
39	Kitchen	20:37:20	0.107	–	5	0.83
40	Kitchen	20:38:00	0.107	–	5	0.83
41	Heat-retention	20:57:00	–	0.530	–	–
42	Heat-retention	21:27:00	–	0.530	–	–
43	Heat-retention	21:57:00	–	0.530	–	–
44	Lavatory	22:00:00	1.286	–	5	10.00
45	Lavatory	22:02:30	0.107	–	5	0.83
46	Lavatory	22:03:10	0.107	–	5	0.83
47	Lavatory	22:03:50	0.107	–	5	0.83
48	Shower	22:14:00	2.571	–	10	20.00
49	Lavatory	22:16:30	0.107	–	5	0.83
50	Lavatory	22:17:10	0.107	–	5	0.83
51	Heat-retention	22:27:00	–	1.020	–	–
52	Shower	22:32:20	6.428	–	10	50.00
53	Lavatory	22:39:20	0.321	–	5	2.50
54	Lavatory	22:40:50	0.107	–	5	0.83
55	Lavatory	22:43:00	0.643	–	5	5.00
56	Lavatory	22:45:00	0.107	–	5	0.83
Total			58.594	4.120	–	455.74

Attachment 2

Water heating and heat-retention mode

(when operations for the same intended usage are summarized)

Heat quantities are those in the winter condition.

No.	Usage	Start time	Heat quantity of hot water heating MJ	Heat quantity of heat-retention MJ	Flow rate L/min	Hot water supply amount L
1	Lavatory	7:00:00	1.713	–	5	13.32
2	Kitchen	8:25:00	4.392	–	5	34.16
3	Kitchen	13:05:00	2.463	–	5	19.16
4	Kitchen	18:25:00	2.890	–	5	22.48
5	Bath	19:40:00	23.143	–	10-15	180.00
6	Kitchen	20:01:00	1.607	–	5	12.50
7	Shower	20:08:00	2.571	–	10	20.00
8	Kitchen	20:16:00	0.963	–	5	7.49
9	Heat-retention	20:27:00	–	1.020	–	–
10	Shower	20:30:00	6.428	–	10	50.00
11	Kitchen	20:37:00	0.427	–	5	3.32
12	Heat-retention	20:57:00	–	1.020	–	–
13	Heat-retention	21:27:00	–	0.530	–	–
14	Heat-retention	21:57:00	–	0.530	–	–
15	Lavatory	22:02:00	1.606	–	5	12.49
16	Shower	22:14:00	2.571	–	10	20.00
17	Lavatory	22:17:00	0.213	–	5	1.66
18	Heat-retention	22:27:00	–	1.020	–	–
19	Shower	22:32:20	6.428	–	10	50.00
20	Lavatory	22:43:00	1.178	–	5	9.16
Total			58.594	4.120	–	455.74

Attachment 3

Water heating and heat-retention mode for household with fewer family members

Heat quantities are those in the winter condition.

No.	Usage	Start time	Heat quantity of hot water heating MJ	Heat quantity of heat-retention MJ	Flow rate L/min	Hot water supply amount L
1	Lavatory	7:00:00	0.643	–	5	5.00
2	Lavatory	7:02:30	0.107	–	5	0.83
3	Lavatory	7:03:10	0.107	–	5	0.83
4	Kitchen	8:15:00	0.129	–	5	1.00
5	Kitchen	8:16:30	0.107	–	5	0.83
6	Kitchen	8:17:10	0.107	–	5	0.83
7	Kitchen	8:27:20	1.286	–	5	10.00
8	Kitchen	8:34:20	0.129	–	5	1.00
9	Kitchen	13:00:00	0.129	–	5	1.00
10	Kitchen	13:01:30	0.107	–	5	0.83
11	Kitchen	13:02:10	0.107	–	5	0.83
12	Kitchen	13:07:20	0.514	–	5	4.00
13	Kitchen	13:10:20	0.129	–	5	1.00
14	Kitchen	18:15:00	0.193	–	5	1.50
15	Kitchen	18:16:30	0.107	–	5	0.83
16	Kitchen	18:18:40	0.257	–	5	2.00
17	Kitchen	18:24:40	0.172	–	5	1.34
18	Kitchen	18:26:50	0.107	–	5	0.83
19	Kitchen	18:27:30	0.107	–	5	0.83
20	Kitchen	18:32:40	0.214	–	5	1.66
21	Kitchen	20:00:00	0.514	–	5	4.00
22	Kitchen	20:02:30	0.129	–	5	1.00
23	Kitchen	20:12:00	0.171	–	5	1.33
24	Kitchen	20:18:10	0.214	–	5	1.66
25	Kitchen	20:37:00	0.171	–	5	1.33
26	Bath	20:40:00	19.285	–	10-15	150.00
27	Shower	21:08:00	2.571	–	10	20.00
28	Heat-retention	21:27:00	–	0.850	–	–
29	Heat-retention	21:57:00	–	0.442	–	–
30	Heat-retention	22:27:00	–	0.442	–	–
31	Shower	22:32:20	6.428	–	10	50.00
32	Lavatory	22:39:20	0.910	–	5	7.08
33	Lavatory	22:42:00	0.214	–	5	1.67
34	Lavatory	22:44:30	0.375	–	5	2.92
Total			35.737	1.734	–	277.96

Water heating and heat-retention mode for household with fewer family members (when operations for the same intended usage are summarized)

Heat quantities are those in the winter condition.

No.	Usage	Start time	Heat quantity of hot water heating MJ	Heat quantity of heat-retention MJ	Flow rate L/min	Hot water supply amount L
1	Lavatory	7:00:00	0.856	–	5	6.66
2	Kitchen	8:25:00	1.757	–	5	13.66
3	Kitchen	13:05:00	0.985	–	5	7.66
4	Kitchen	18:25:00	1.156	–	5	8.99
5	Kitchen	20:01:00	0.643	–	5	5.00
6	Kitchen	20:16:00	0.385	–	5	3 00
7	Kitchen	20:37:00	0.171	–	5	1.33
8	Bath	20:40:00	19.285	–	10-15	150.00
9	Shower	21:08:00	2.571	–	10	20.00
10	Heat-retention	21:27:00	–	0.850	–	–
11	Heat-retention	21:57:00	–	0.442	–	–
12	Heat-retention	22:27:00	–	0.442	–	–
13	Shower	22:32:20	6.428	–	10	50.00
14	Lavatory	22:43:00	1.498	–	5	11.66
Total			35.737	1.734	–	277.96

Attachment 6

Heat Pump Water Heater Evaluation Standards Subcommittee,
Energy Efficiency Standards Subcommittee of the Advisory Committee
for Natural Resources and Energy
Meeting History

First Subcommittee Meeting (July 20, 2010)
- Disclosure of the Heat Pump Water Heater Evaluation Standards Subcommittee
- Current status of heat pump water heaters
- Scope of heat pump water heaters
- Energy consumption efficiency of heat pump water heaters and its measurement method

Second Subcommittee Meeting (March 28, 2012)
- Classification of heat pump water heaters
- Target fiscal year and target standard values for heat pump water heaters

Third Subcommittee Meeting (April 17, 2012)
- Interim report on heat pump water heaters

Attachment 7

Heat Pump Water Heater Evaluation Standards Subcommittee,
Energy Efficiency Standards Subcommittee of the Advisory Committee
for Natural Resources and Energy
List of Members

Chairman	Motoyasu Kamata	Professor Emeritus, The University of Tokyo
Members	Yukie Iino	Researcher, Consumer Lives Research Center, Japan Consumer's Association
	Tadayoshi Tanaka	General Manager, Technology Planning and Management Department, The Energy Conservation Center, Japan (Replaced by committee member Inoue from the second meeting)
	Mamoru Inoue	General Manager, Technology Planning and Management Department, The Energy Conservation Center, Japan (Joined from the second meeting)
	Shinya Okada	Deputy Chairman, Heat Pump Water Heater Committee, The Japan Refrigeration and Air Conditioning Industry Association
	Kiyoshi Saito	Professor, Faculty of Science and Engineering, Waseda University
	Masako Sugimoto	Director, Nippon Association of Consumer Specialists
	Hirofumi Daiguji	Associate Professor, Graduate School of Frontier Sciences, The University of Tokyo
	Koichi Takubo	Manager, Business Department, The Federation of Electric Power Companies of Japan
	Chiharu Murakoshi	Vice President, Jyukankyo Research Institute Inc.

Reference

Status Quo of Heat Pump Water Heaters

July 22, 2010

Ministry of Economy, Trade and Industry
Commerce and Information Policy Bureau
Information and Communication
Electronics Division

1. What is Heat Pump Water Heater?

- **Heat pump water heaters**
  - ✓ A collective name for water heaters using the principle of heat pump as in the case of air conditioners. They are considered as products excellent in energy saving performance. There are residential heat pump water heaters and commercial heat pump water heaters.

* The name “EcoCute” is a registered trade name of the Kansai Electric Power Co., Inc., which is used by many companies with the permission of said company.

■ Features

✓ The heat pump unit ((1) in the right figure) efficiently makes a large amount of hot water, and then it is stored (storage temperature at 65 to 90℃) in the hot water storage unit ((2) in the right figure). Hot water is served from the storage unit when it is used at baths, lavatories, kitchens, etc.

✓ Residential heat pump water heaters generally make hot water using less expensive nighttime electricity, so their electric bill is relatively low.

■ Refrigerant used

✓ Heat pump water heaters using HFC (fluorocarbon) as refrigerant are conventionally available in the market. However, those using carbon dioxide (CO_2) as refrigerant were developed in 2001, and the demands, especially for residential models, has been expanding. (Some commercial models are still using HFC.)

2. Types of Heat Pump Water Heaters (1)

- **Residential heat pump water heaters**
  - ✓ Residential heat pump water heaters are classified into several types according to their tank shape, capacity, function, etc. The capacity ranges from 370 to 460 L in case of products for standard households (4 family members) and from 150 to 200 L in case of compact tanks (for a single, 2 family members, etc.).

1. Types by tank shape and capacity


<Standard tank>


<Thin tank>


<Compact tank>


<All-in-one type>

2. Types by function

a. Full-auto type
Those equipped with functions of “automatic hot water filling”, “hot water adding”, “automatic heat-retention” and “reheating” for bath.

b. Auto (semi-auto) type
Those equipped with functions of “automatic hot water filling” and “hot water adding” for bath.

c. Hot water supply only type
Those designed only for hot water supply, so they fill a bath with hot water through a faucet.

d. Multifunction type
Those equipped with a floor heating function in addition to a hot water supply function for bath, lavatory, kitchen, etc.

3. Types of Heat Pump Water Heaters (2)

- **Commercial heat pump water heaters**
  Commercial heat pump water heaters are used in commercial facilities such as buildings, hotels, etc. Following types are available according to their scales and hot water amount used.

<For small scale buildings>

- ✓ Clinics, inns, small welfare facilities, etc.
- ✓ Restaurants, shops, etc.

<For large scale buildings>

- ✓ Hospitals, hotels, large welfare facilities
- ✓ Sports spa facilities, meal supply facilities, etc.

4. Shipping Quantity of Heat Pump Water Heaters (1) (Residential)

■ **Residential heat pump water heaters**

✓ Shipping quantity of residential heat pump water heaters started to rapidly increase in around year 2002 (*), making cumulative shipping quantity reach approximately 2.25 million units. Shipment quantity in FY2009 is 508 thousand units, and the market size remains at around 500 thousand units likewise in the previous year.

✓ Main manufacturers are the following 12 companies, and there are few imported products sold in the market.

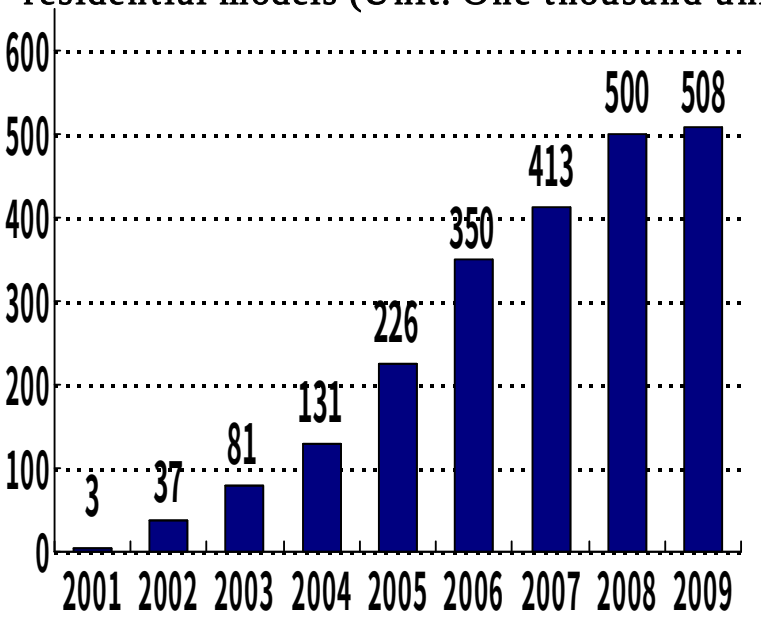
* A "subsidy system" in which the government bears part of the cost to install heat pump water heaters (CO_2 refrigerant) was implemented in FY2002. Since then, thanks to this subsidy system in part, the number of installed units has rapidly increased.

● **Main manufacturers of residential products**

Corona Corporation
Sanden Corporation
SANYO Electric Co., Ltd.
Daikin Industries, Ltd.
Choshu Industry Co., Ltd.
CHOFU SEISAKUSHO Co., Ltd.
DENSO Corporation
TOSHIBA CARRIER Corporation
Housetec Inc.
Panasonic Corporation
Hitachi Appliances, Inc.
Mitsubishi Electric Corporation

(In Japanese alphabetical order)

● **Transition of shipping quantity of residential models (Unit: One thousand units)**



Data provided by The Japan Refrigeration and Air Conditioning Industry Association

5. Shipping Quantity of Heat Pump Water Heaters (2) (Commercial)

■ **Commercial Heat Pump Water Heaters**

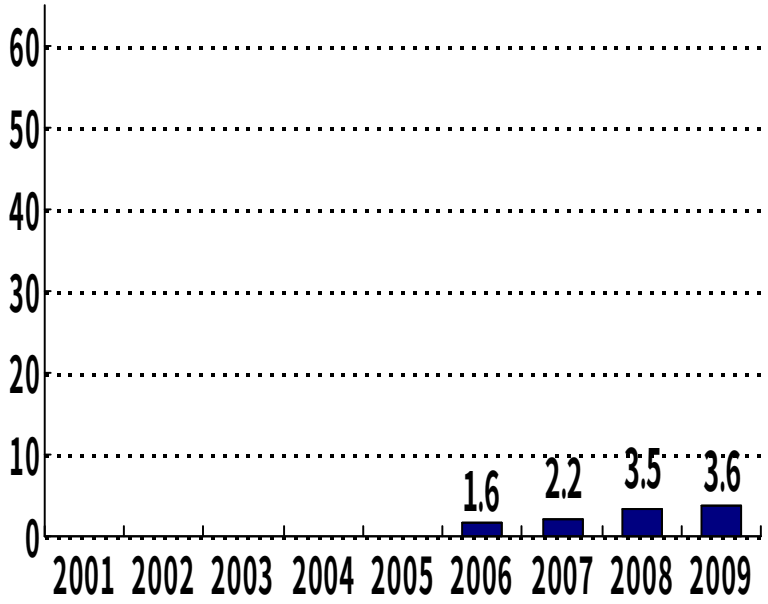
✓ Shipping quantity of commercial heat pump water heaters in FY2009 is 3.6 thousand units, and its cumulative shipping quantity is 10 thousand plus units. Its market size is small compared with that of residential models, occupying only less than 1% of the heat pump water heater market as a whole.

✓ Main manufacturers are the following companies, and there are few imported products.

● **Main manufacturers of commercial products**

Showa Manufacturing Co., Ltd.
Daikin Industries, Ltd.
DENSO Corporation
TOSHIBA CARRIER Corporation
Nihon Itomic Co., Ltd.
Panasonic Corporation
Hitachi Appliances, Inc.
MAYEKAWA MFG. Co., Ltd.
Mitsubishi Electric Corporation
(In Japanese alphabetical order)

● **Transition of shipping quantity, commercial (Unit: One thousand units)**



Data provided by The Japan Refrigeration and Air Conditioning Industry Association

6. Technology of Heat Pump Water Heaters (1)

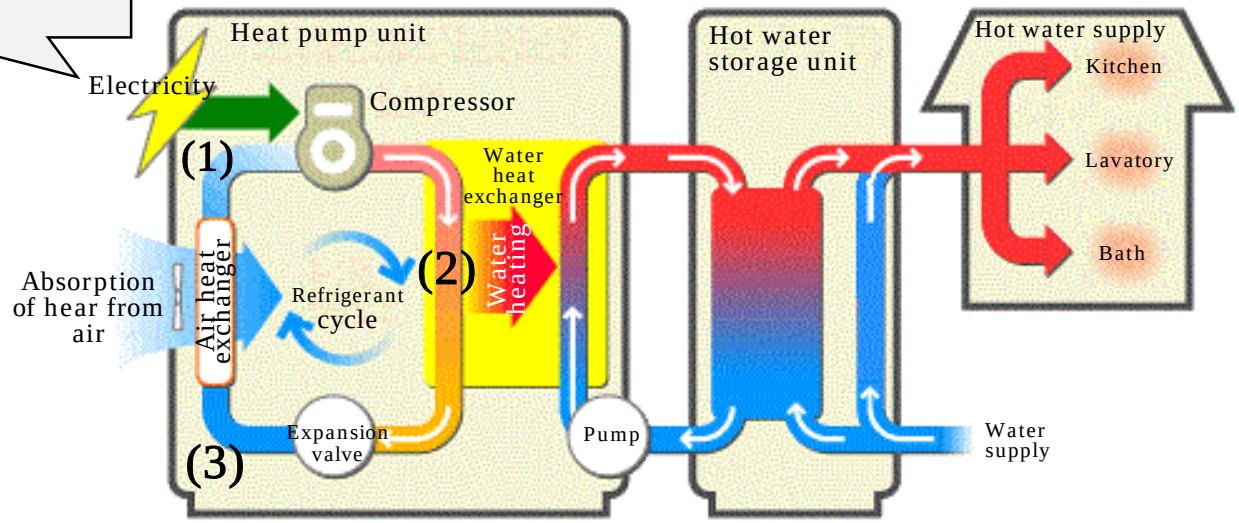
■ **Principle of making hot water**

Using the "principle of heat pump" which is also employed in air conditioners, heat pump water heaters make hot water through the compression-expansion cycle of refrigerant, store it in a hot water storage tank and supply it.

(1) A heat pump water heater makes its refrigerant to absorb heat from air through an "air heat exchanger" and compresses the refrigerant with a compressor to bring it into a high temperature and high pressure state. (2) Then, the heat of the refrigerant is transferred to water through a "water heat exchanger", and the produced hot water is stored in a hot water storage tank. (3) The refrigerant which lost heat is expanded by an expansion valve to bring it back to a low temperature and low pressure state again in which it can easily absorb heat from air. A heat pump water heater is a mechanism repeating this procedure.

•In a heat pump unit, hot water is made through heat exchange using the heat of air.

* Hot water stored in the hot water storage unit is kept hot and used according to the purpose of use.

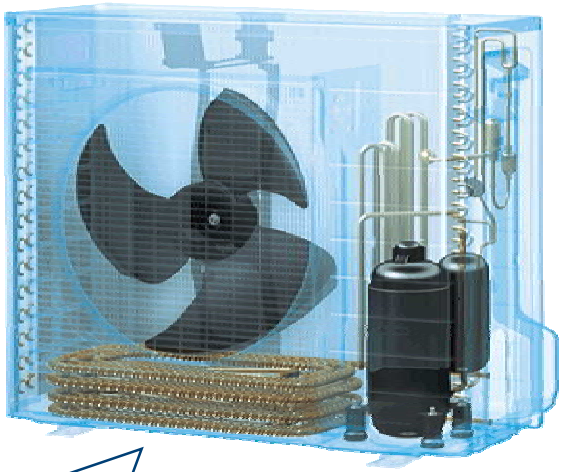


7. Technology of Heat Pump Water Heaters (2)

■ **Toward further energy saving**

To realize further energy saving, efficiency of every component is being enhanced.
(1) As for technologies of the heat pump side, efficiency improvement of heat exchangers, compressors, etc. is being worked on. (Figure (1) below shows an example of efficiency improvement made to a water heat exchanger.)
(2) As for technologies of the hot water storage unit side, improvement of thermal insulation performance by using vacuum thermal insulation materials, etc. is being worked on. (Figure (2) below shows an example of vacuum thermal insulation material.)

(1)

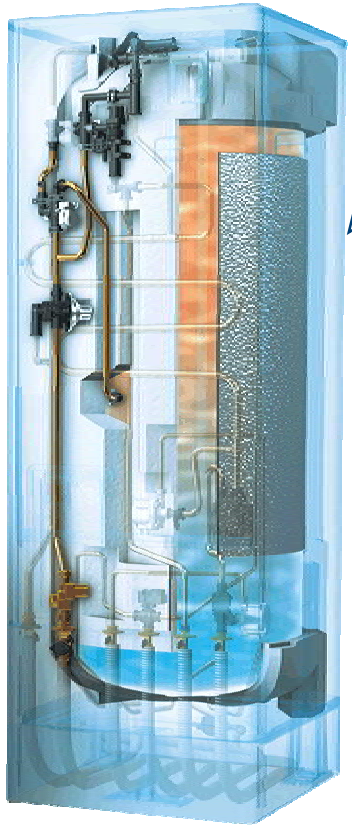


(Dimple refrigerant tube)

(Corrugated water tube)

<Water heat exchanger>
Pressure loss of refrigerant is reduced by taking advantage of the shape of refrigerant tubes and water tubes. Meanwhile, heat exchange efficiency is improved by expanding the heat exchange area.

(2)



(Vacuum thermal insulation material)

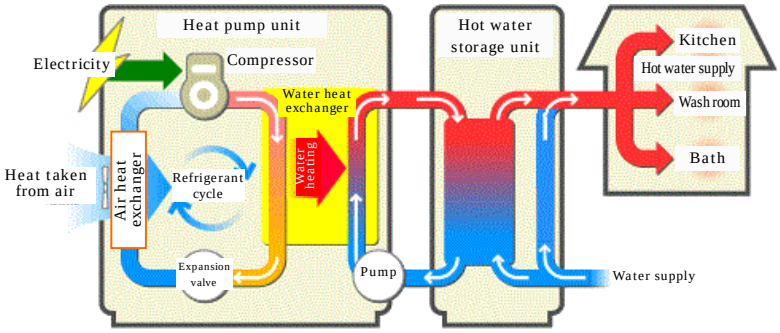
<Vacuum thermal insulation material>
Efficiency is improved by adopting vacuum thermal insulation materials whose thermal insulation performance is better than those of conventional glass wool or foamed polystyrene.

Attachment

Methods for Measurement and Calculation of Annual Efficiency of Water Heating's Heat-retention (for Products with a Heat-retention Function)

1. Procedures for measurement and calculation of annual efficiency of water heating's heat-retention

A residential heat pump water heater is composed of a "heat pump unit" and a "hot water storage unit".



Composition of residential heat pump water heater

- Specific procedures for the measurement and calculation of the energy consumption efficiency are as follows.

[Procedure (1)] Calculation of "efficiency of water heating's heat-retention mode" of a system as a whole

- The measurement is performed under the "water heating's heat-retention mode (winter conditions)" considering actual usage conditions.

[Procedure (2)] Calculation of "heat pump unit's single unit efficiency"

- The measurement is performed under 6 temperature conditions (i.e. standard heating conditions (middle season, summer and winter), high temperature heating conditions (winter and frosting season) and water heating mode's heating conditions).

* As regards the specifications for cold areas, the measurement is additionally performed under cold area winter's high temperature heating conditions.

[Procedure (3)] Calculation of "annual efficiency of water heating's heat-retention"

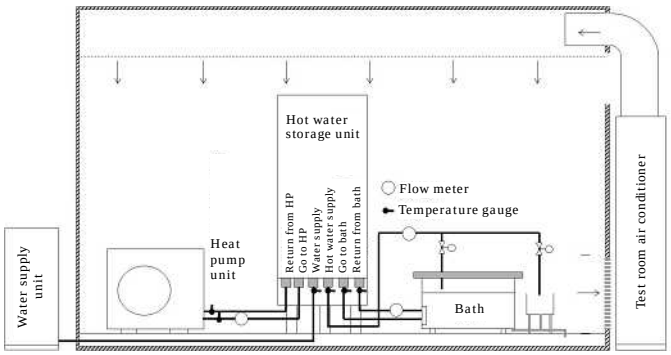
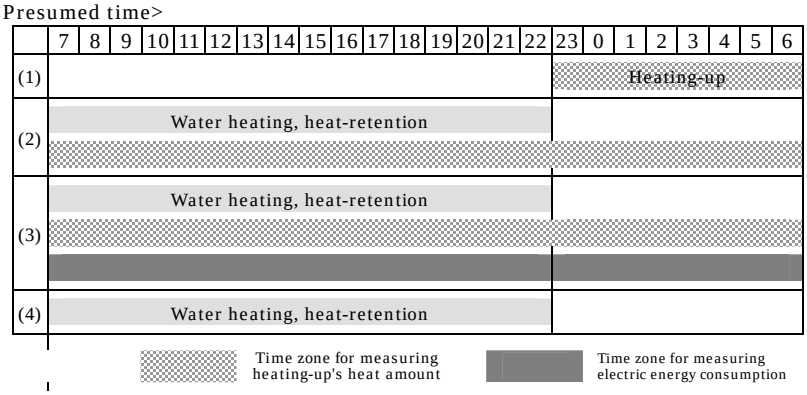
(1) A factor is obtained from the "efficiency of water heating's heat-retention mode" and the "heat pump unit's single unit efficiency" under winter conditions, and the "efficiency of water heating's heat-retention mode" under each outside temperature is calculated based on the factor.

(2) The "annual heat amount of water heating's heat-retention" is calculated from the number of days when applicable outside temperature has occurred and the in-coming water temperature.

(3) The "electric energy consumption" is obtained from the "heat amount of water heating's heat-retention mode" and the "efficiency of water heating's heat-retention mode" under each outside temperature, and the "annual electric energy consumption" is calculated from the their total.

(4) The "annual efficiency of water heating's heat-retention" is calculated from the "annual heat amount of water heating's heat-retention" and the "annual electric energy consumption".

2. Outline of methods for the measurement and calculation of annual efficiency of water heating's heat-retention

Items		Outline - In case of products with a bath heat-retention function -
Procedure (1) Calculation of "efficiency of water heating heat-retention mode"	Temperature condition	Air temperature: Dry bulb 7.0±1°C, wet bulb 6.0±0.5°C Water temperature: Water supply temperature 9.0±2.0°C
	Test equipment	Placement of test equipment and measurement instruments of a heat pump water heater (Example)  Measurement instruments a) The temperature gauge for the measurement of water supply temperature and hot water supply temperature and the flow meter for the measurement of hot water supply amount b) The temperature gauge for the measurement of going-to-bath temperature and returning-from-bath temperature and the flow meter for the measurement of hot water amount c) The integrating watt meter for the measurement of electric power consumption of a residential heat pump water heater d) The temperature gauge and the flow meter for the measurement of incoming water temperature and outgoing hot water temperature of the heat pump e) The thermocouple for the confirmation of the heat amount of the hot water remaining in the hot water storage tank.
	Operation state	The test is conducted by operating a residential heat pump water heater under the rated frequency and the rated voltage (the tolerance must be within ±2% of each rating). The residential heat pump water heater is operated with the operational setting preset at the time of shipment. However, in case of a product equipped with a learning control function, it is operated with the operational setting preset at the time of shipment until the operation is stabilized under the water heating's heat-retention mode. If remaining hot water amount after the operation is stabilized is below 100 L, when converted to that of 40°C, the test operation setting must be that which makes the remaining hot water amount 100 L or above, when converted to that of 40°C. The method for setting this test operation must be described in technical data. The heating-up temperature in the test operation setting must be the heating-up temperature appearing when the operation is stabilized under the water heating's heat-retention mode operated with the operational setting preset at the time of shipment or above that.
	Water heating heat-retention's heat amount	Water heating's heat-retention mode: "Water heating's standard usage mode of bathtubs with a water heater" of JIS S 2072 is adopted (Attachment 1). * To enhance the accuracy of the measurement of the water heating's heat amount, a mode integrating continuous use is set (Attachment 2). (As the hot water supply mode, the "standard usage mode of hot water supply equipment used in kitchens, washing rooms, showers and baths" of TS S 0003 is adopted.)
	Test method	The test of the hot water supply mode's performance is conducted with the following schedule, and the heat amount of water heating's heat-retention and the electric energy consumption on the third day are measured. The water heating's heat amount of each day must be within the range of ±5%, and the heating-up's heat amount on the second and third days must be within the range of ±5%. <Presumed time> 

Items		Outline - In case of products with a bath heat-retention function -
Procedure (1) Calculation of "efficiency of water heating heat-retention mode" of the system as a whole	Calculation formula	The efficiency of water heating's heat-retention mode is calculated by the following formula. Efficiency of water heating's heat-retention mode $C_{MW1} = \frac{Q_{MW1}}{P_{MW1} \times 3.6}$ Here: C_{MW1}: Efficiency of water heating's heat-retention mode Q_{MW1}: Heat amount of water heating's heat-retention mode (MJ) <- Total of water heating's heat amount and heat-retention's heat amount of one day P_{MW1}: Electric energy consumption of water heating's heat-retention mode (kWh) <- Electric energy consumption of one day when operating under water heating's heat-retention mode 3.6: Factor for converting kWh to MJ Water heating's heat amount $Q = \sum_{j=t_s}^{t_e} \left\{ (T_m - T_i) \times q_m \times \rho \times c_p \times t_m \right\}$ Here: Q: Heat amount of each water heating mode (kJ) j: Classification numbered for each measurement interval T_m: Water heating temperature (°C) t_s: Time when hot water supply starts t_e: Time when hot water supply ends T_i: Water supply temperature when simultaneously measuring each hot water supply temperature (°C) ρ: Water density at each hot water supply temperature (kg/L).....(from Table A.4) c_p: Average specific heat of water 4.1796 (kJ/kg･°C).....(constant value) q_m: Flow rate in measurement interval (L/min) t_m: Measurement interval (min) Heat-retention's heat amount $Q_k = \sum_{j=t_s}^{t_e} \left\{ (T_{ok} - T_{ik}) \times q_k \times \rho \times c_p \times t_k \right\}$ Here: Q_k: Heat amount of each heat-retention mode (kJ) j: Classification numbered for each measurement interval T_{oK}: Going-to-bath temperature (°C) t_s: Time when valid water heating's heat amount starts t_e: Time when hot water supply ends T_{ik}: Returning-from-bath temperature when simultaneously measuring going-to-bath temperature (°C) ρ: Water density at going-to-bath temperature (kg/L)..... (from Table A.4) c_p: Average specific heat of water 4.1796 (kJ/kg･°C)..... (constant value) q_k: Flow rate in measurement interval (L/min) t_m: Measurement interval (min) Integration is made when $T_{oK} > T_{ik}$ condition is met.

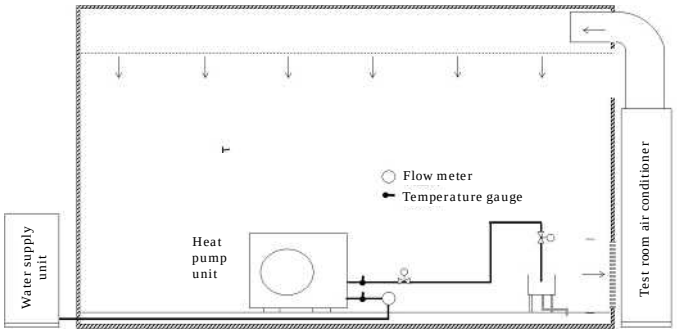
Items		Outline - In case of products with a bath heat-retention function -
Procedure (2) Calculation of "heat pump unit's single unit efficiency"	Temperature conditions	Unit: °C

Conditions	Setting of hot water temperature	Inlet air temperature		Water temperature	Procedure (3)
		Dry bulb temperature	Wet bulb temperature	In-coming water temperature	COP performance line No.
Middle season standard heating condition	Standard heating-up temperature	16	12	17	(2)
Summer standard heating condition	Standard heating-up temperature	25	21	24	(3)
Winter standard heating condition	Standard heating-up temperature	7	6	9	(1)
Winter high temperature heating condition	Winter high temperature heating-up temperature	7	6	9	(4)
Frosting season high temperature heating condition	Frosting season high temperature heating-up temperature	2	1	5	(5)
Cold area winter high temperature heating condition	Cold area winter high temperature heating-up temperature	–7	–8	5	(6)
Water heating mode heating condition	Heating-up temperature at the time of water heating mode performance test	7	6	9	(8)

* The performance test under the cold area winter high temperature heating condition is implemented for products with cold area specifications.

Test equipment

Placement of test equipment (Example)



Test method

a) Measurement under steady condition
The measurement is implemented 7 times at 5 minute intervals after operating the unit for 1 hour or more after the test condition reaches steady condition.

b) Measurement under transient condition
A heating capacity test for heat pumps in a frosty area.

Calculation formula

The "heat pump unit's single unit efficiency" under each condition is calculated by dividing the heating capacity calculated with the following method by the electric power consumption at the time of steady condition. The heating capacity is calculated by the following formula, using the average of measured values.

$$\Phi = (T_2 - T_1) \cdot qr \cdot c_p$$

Here: Φ: Total heating capacity of a heat pump calculated from the heat exchange amount of the heat exchanger of the use side.

T_1: Water temperature at the inlet of the heat exchanger of the use side (°C)

T_2: Water temperature at the outlet of the heat exchanger of the use side (°C)

c_p: Specific heat of water (J/kg°C)

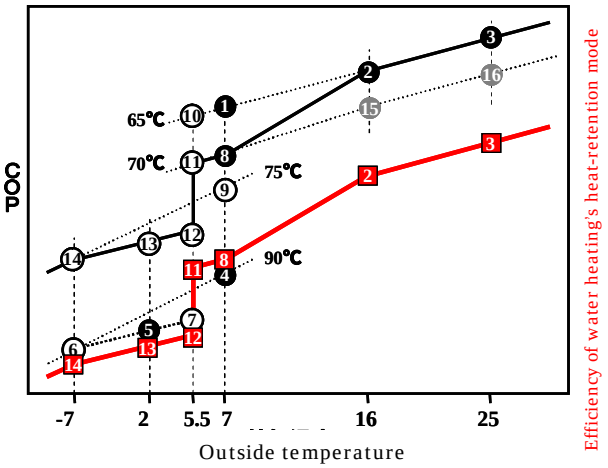
qr: Mass flow rate of the heat exchanger of the use side (kg/s)

=> The energy consumption efficiency of water heating's heat-retention mode C_{HMT1} is the "heat pump unit's single unit efficiency" under the heating-up temperature at the time of the performance test of the water heating mode.

Items		Outline - In case of products with a bath heat-retention function -
Procedure (3) Calculation of "annual efficiency of water heating's heat-retention"	Water heating's heat-retention efficiency factor of a heat pump	The ratio between the efficiency of water heating's heat-retention mode C_{MW1} calculated in the procedure (1) and the energy consumption efficiency of water heating's heat-retention mode C_{HMT1} calculated in the procedure (2). The water heating's heat-retention efficiency factor F_{HM1} of a heat pump is calculated by the following formula. $$F_{HM1} = \frac{C_{MW1}}{C_{HMT1}}$$ Here: C_{HMT1}: Energy consumption efficiency of water heating's heat-retention mode ← From the procedure (2) C_{MW1}: Efficiency of water heating's heat-retention mode ← From the procedure (1)
	Temperature condition	Number of days when the listed average outside nighttime temperature has occurred in a year.

Temperature category *j*	Outside temperature *tj* ℃	Number of days *dj* d	Temperature category *j*	Outside temperature *tj* ℃	Number of days *dj* d	Temperature category *j*	Outside temperature *tj* ℃	Number of days *dj* d
1	–10	0	16	5	17	31	20	15
2	–9	0	17	6	17	32	21	15
3	–8	0	18	7	15	33	22	13
4	–7	0	19	8	15	34	23	14
5	–6	0	20	9	13	35	24	11
6	–5	0	21	10	12	36	25	12
7	–4	0	22	11	11	37	26	13
8	–3	0	23	12	12	38	27	14
9	–2	0	24	13	10	39	28	15
10	–1	0	25	14	12	40	29	7
11	0	1	26	15	13	41	30	2
12	1	1	27	16	13	42	31	0
13	2	5	28	17	14	43	32	0
14	3	9	29	18	15	–	–	–
15	4	15	30	19	14	Total		365

Items		Outline - In case of products with a bath heat-retention function -
	Calculation formula	I) From the heat pump unit's single unit efficiency (COP) measured under each condition as described in the procedure (2), the heat pump unit's single unit efficiency (COP) under each outside temperature and each hot water temperature is calculated (Right figure: COP performance line). II) From the water heating's heat-retention efficiency factor F_{HM1} of a heat pump and the heat pump's single unit efficiency under each outside temperature and each hot water temperature, the efficiency of water heating's heat-retention mode C_{M1} (tj) under each outside temperature is calculated (Right figure: Efficiency performance line of water heating's heat-retention mode).

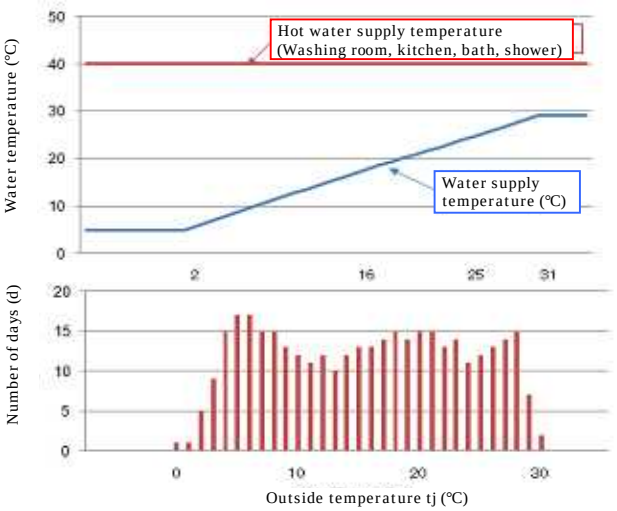


III) The annual heat amount of water heating's heat-retention QMA1 is calculated by multiplying the heat amount of water heating's heat-retention QM1 (tj) under outside temperature tj by the number of days when the outside temperature was tj, then by totaling them.

$$Q_{MA1}=\sum_{j=1}^{43}\{Q_{M1}(tj)\cdot dj\}$$

IV) The electric energy consumption P_{M1} (tj) under outside temperature tj is calculated by dividing the heat amount of water heating's heat-retention Q_{M1} (tj) under the outside temperature tj by the efficiency of water heating's heat-retention mode C_{M1} (tj), and the annual electric energy consumption P_{MA1} of water heating's heat-retention mode is calculated by multiplying the electric energy consumption calculated above by the number of days when outside temperature was tj, then by totaling them.

$$P_{MA1}=\sum_{j=1}^{43}\left\{\frac{Q_{M1}(tj)}{C_{M1}(tj)\times 3.6}\times dj\right\}$$



V) The annual efficiency of water heating's heat-retention C_{MA1} is calculated by the following formula.

$$C_{MA1}=\frac{Q_{MA1}}{P_{MA1}\times 3.6}$$

Here:

C_{MA1}: Annual efficiency of water heating's heat-retention when performing water heating's heat-retention under water heating's heat-retention mode

Q_{MA1}: Annual heat amount of water heating's heat-retention mode (MJ)

P_{MA1}: Annual electric energy consumption of water heating's heat-retention mode (kWh)

3.6: Factor for converting kWh to MJ

Others	For households with only a few members	To be evaluated by changing the load of water heating's heat-retention to the water heating's heat-retention mode for households with only a few members (stipulation). * A mode integrating the water heating's heat-retention mode for a few people and the actions for continuing same use is created (Attachment 3).

Items		Outline - In case of products with a bath heat-retention function -
	Specifications for cold areas	The annual efficiency of water heating's heat-retention is calculated by replacing the foregoing numbers of the outside temperature, water supply temperature and number of days with the following numbers. The annual efficiency of water heating's heat-retention is indicated too for reference.

II Area (Morioka)

Temperature Category *j*	Outside temperature *tj* ℃	Number of days *dj* d	Temperature Category *j*	Outside temperature *tj* ℃	Number of days *dj* d	Temperature Category *j*	Outside temperature *tj* ℃	Number of days *dj* d
1	–10	0	16	5	10	31	20	11
2	–9	1	17	6	11	32	21	9
3	–8	2	18	7	11	33	22	9
4	–7	3	19	8	9	34	23	9
5	–6	5	20	9	10	35	24	6
6	–5	8	21	10	9	36	25	4
7	–4	11	22	11	10	37	26	1
8	–3	13	23	12	11	38	27	0
9	–2	15	24	13	11	39	28	0
10	–1	16	25	14	12	40	29	0
11	0	20	26	15	13	41	30	0
12	1	16	27	16	15	42	31	0
13	2	13	28	17	15	43	32	0
14	3	11	29	18	13	–	–	–
15	4	9	30	19	13	Total		365

To calculate the yearly efficiency of water heating's heat-retention in the specifications for cold areas, heat pump unit's single unit efficiency under the following condition is actually measured.

Unit: ℃

Condition	Setting of out-going hot water temperature	Inlet air temperature		Water temperature
		Dry bulb temperature	Wet bulb temperature	In-coming water temperature
Cold area winter high temperature heating condition	Cold area high temperature heating-up temperature	–7	–8	5

Attachment 1

Water heating and heat-retention mode

Heat quantities are those in the winter condition.

No.	Usage	Start time	Heat quantity of hot water heating MJ	Heat quantity of heat-retention MJ	Flow rate L/min	Hot water supply amount L
1	Lavatory	7:00:00	1.286	–	5	10.00
2	Lavatory	7:02:30	0.107	–	5	0.83
3	Lavatory	7:03:10	0.107	–	5	0.83
4	Lavatory	7:04:20	0.107	–	5	0.83
5	Lavatory	7:05:00	0.107	–	5	0.83
6	Kitchen	8:15:00	0.643	–	5	5.00
7	Kitchen	8:16:30	0.107	–	5	0.83
8	Kitchen	8:17:10	0.107	–	5	0.83
9	Kitchen	8:27:20	3.214	–	5	25.00
10	Kitchen	8:34:20	0.321	–	5	2.50
11	Kitchen	13:00:00	0.643	–	5	5.00
12	Kitchen	13:01:30	0.107	–	5	0.83
13	Kitchen	13:02:10	0.107	–	5	0.83
14	Kitchen	13:07:20	1.286	–	5	10.00
15	Kitchen	13:10:20	0.321	–	5	2.50
16	Kitchen	18:15:00	0.643	–	5	5.00
17	Kitchen	18:16:30	0.107	–	5	0.83
18	Kitchen	18:18:40	0.643	–	5	5.00
19	Kitchen	18:24:40	0.643	–	5	5.00
20	Kitchen	18:26:10	0.107	–	5	0.83
21	Kitchen	18:26:50	0.107	–	5	0.83
22	Kitchen	18:27:30	0.107	–	5	0.83
23	Kitchen	18:32:40	0.321	–	5	2.50
24	Kitchen	18:33:40	0.107	–	5	0.83
25	Kitchen	18:34:20	0.107	–	5	0.83
26	Bath	19:40:00	23.143	–	10-15	180.00
27	Kitchen	20:00:00	1.286	–	5	10.00
28	Kitchen	20:02:30	0.321	–	5	2.50
29	Shower	20:08:00	2.571	–	10	20.00
30	Kitchen	20:12:00	0.321	–	5	2.50
31	Kitchen	20:13:00	0.107	–	5	0.83
32	Kitchen	20:18:10	0.321	–	5	2.50
33	Kitchen	20:19:10	0.107	–	5	0.83
34	Kitchen	20:19:50	0.107	–	5	0.83
35	Heat-retention	20:27:00	–	1.020	–	–
36	Shower	20:30:00	6.428	–	10	50.00
37	Kitchen	20:36:00	0.107	–	5	0.83
38	Kitchen	20:36:40	0.107	–	5	0.83
39	Kitchen	20:37:20	0.107	–	5	0.83
40	Kitchen	20:38:00	0.107	–	5	0.83
41	Heat-retention	20:57:00	–	0.530	–	–
42	Heat-retention	21:27:00	–	0.530	–	–
43	Heat-retention	21:57:00	–	0.530	–	–
44	Lavatory	22:00:00	1.286	–	5	10.00
45	Lavatory	22:02:30	0.107	–	5	0.83
46	Lavatory	22:03:10	0.107	–	5	0.83
47	Lavatory	22:03:50	0.107	–	5	0.83
48	Shower	22:14:00	2.571	–	10	20.00
49	Lavatory	22:16:30	0.107	–	5	0.83
50	Lavatory	22:17:10	0.107	–	5	0.83
51	Heat-retention	22:27:00	–	1.020	–	–
52	Shower	22:32:20	6.428	–	10	50.00
53	Lavatory	22:39:20	0.321	–	5	2.50
54	Lavatory	22:40:50	0.107	–	5	0.83
55	Lavatory	22:43:00	0.643	–	5	5.00
56	Lavatory	22:45:00	0.107	–	5	0.83
Total			58.594	4.120	–	455.74

Attachment 2

Water heating and heat-retention mode

(when operations for the same intended usage are summarized)

Heat quantities are those in the winter condition.

No.	Usage	Start time	Heat quantity of hot water heating MJ	Heat quantity of heat-retention MJ	Flow rate L/min	Hot water supply amount L
1	Lavatory	7:00:00	1.713	–	5	13.32
2	Kitchen	8:25:00	4.392	–	5	34.16
3	Kitchen	13:05:00	2.463	–	5	19.16
4	Kitchen	18:25:00	2.890	–	5	22.48
5	Bath	19:40:00	23.143	–	10-15	180.00
6	Kitchen	20:01:00	1.607	–	5	12.50
7	Shower	20:08:00	2.571	–	10	20.00
8	Kitchen	20:16:00	0.963	–	5	7.49
9	Heat-retention	20:27:00	–	1.020	–	–
10	Shower	20:30:00	6.428	–	10	50.00
11	Kitchen	20:37:00	0.427	–	5	3.32
12	Heat-retention	20:57:00	–	1.020	–	–
13	Heat-retention	21:27:00	–	0.530	–	–
14	Heat-retention	21:57:00	–	0.530	–	–
15	Lavatory	22:02:00	1.606	–	5	12.49
16	Shower	22:14:00	2.571	–	10	20.00
17	Lavatory	22:17:00	0.213	–	5	1.66
18	Heat-retention	22:27:00	–	1.020	–	–
19	Shower	22:32:20	6.428	–	10	50.00
20	Lavatory	22:43:00	1.178	–	5	9.16
Total			58.594	4.120	–	455.74

Attachment 3

Water heating and heat-retention mode for household with fewer family members

Heat quantities are those in the winter condition.

No.	Usage	Start time	Heat quantity of hot water heating MJ	Heat quantity of heat-retention MJ	Flow rate L/min	Hot water supply amount L
1	Lavatory	7:00:00	0.643	–	5	5.00
2	Lavatory	7:02:30	0.107	–	5	0.83
3	Lavatory	7:03:10	0.107	–	5	0.83
4	Kitchen	8:15:00	0.129	–	5	1.00
5	Kitchen	8:16:30	0.107	–	5	0.83
6	Kitchen	8:17:10	0.107	–	5	0.83
7	Kitchen	8:27:20	1.286	–	5	10.00
8	Kitchen	8:34:20	0.129	–	5	1.00
9	Kitchen	13:00:00	0.129	–	5	1.00
10	Kitchen	13:01:30	0.107	–	5	0.83
11	Kitchen	13:02:10	0.107	–	5	0.83
12	Kitchen	13:07:20	0.514	–	5	4.00
13	Kitchen	13:10:20	0.129	–	5	1.00
14	Kitchen	18:15:00	0.193	–	5	1.50
15	Kitchen	18:16:30	0.107	–	5	0.83
16	Kitchen	18:18:40	0.257	–	5	2.00
17	Kitchen	18:24:40	0.172	–	5	1.34
18	Kitchen	18:26:50	0.107	–	5	0.83
19	Kitchen	18:27:30	0.107	–	5	0.83
20	Kitchen	18:32:40	0.214	–	5	1.66
21	Kitchen	20:00:00	0.514	–	5	4.00
22	Kitchen	20:02:30	0.129	–	5	1.00
23	Kitchen	20:12:00	0.171	–	5	1.33
24	Kitchen	20:18:10	0.214	–	5	1.66
25	Kitchen	20:37:00	0.171	–	5	1.33
26	Bath	20:40:00	19.285	–	10-15	150.00
27	Shower	21:08:00	2.571	–	10	20.00
28	Heat-retention	21:27:00	–	0.850	–	–
29	Heat-retention	21:57:00	–	0.442	–	–
30	Heat-retention	22:27:00	–	0.442	–	–
31	Shower	22:32:20	6.428	–	10	50.00
32	Lavatory	22:39:20	0.910	–	5	7.08
33	Lavatory	22:42:00	0.214	–	5	1.67
34	Lavatory	22:44:30	0.375	–	5	2.92
Total			35.737	1.734	–	277.96

Water heating and heat-retention mode for household with fewer family members (when operations for the same intended usage are summarized)

Heat quantities are those in the winter condition.

No.	Usage	Start time	Heat quantity of hot water heating MJ	Heat quantity of heat-retention MJ	Flow rate L/min	Hot water supply amount L
1	Lavatory	7:00:00	0.856	–	5	6.66
2	Kitchen	8:25:00	1.757	–	5	13.66
3	Kitchen	13:05:00	0.985	–	5	7.66
4	Kitchen	18:25:00	1.156	–	5	8.99
5	Kitchen	20:01:00	0.643	–	5	5.00
6	Kitchen	20:16:00	0.385	–	5	3 00
7	Kitchen	20:37:00	0.171	–	5	1.33
8	Bath	20:40:00	19.285	–	10-15	150.00
9	Shower	21:08:00	2.571	–	10	20.00
10	Heat-retention	21:27:00	–	0.850	–	–
11	Heat-retention	21:57:00	–	0.442	–	–
12	Heat-retention	22:27:00	–	0.442	–	–
13	Shower	22:32:20	6.428	–	10	50.00
14	Lavatory	22:43:00	1.498	–	5	11.66
Total			35.737	1.734	–	277.96

Attachment 6

Heat Pump Water Heater Evaluation Standards Subcommittee,
Energy Efficiency Standards Subcommittee of the Advisory Committee
for Natural Resources and Energy
Meeting History

First Subcommittee Meeting (July 20, 2010)
- Disclosure of the Heat Pump Water Heater Evaluation Standards Subcommittee
- Current status of heat pump water heaters
- Scope of heat pump water heaters
- Energy consumption efficiency of heat pump water heaters and its measurement method

Second Subcommittee Meeting (March 28, 2012)
- Classification of heat pump water heaters
- Target fiscal year and target standard values for heat pump water heaters

Third Subcommittee Meeting (April 17, 2012)
- Interim report on heat pump water heaters

Attachment 7

Heat Pump Water Heater Evaluation Standards Subcommittee,
Energy Efficiency Standards Subcommittee of the Advisory Committee
for Natural Resources and Energy
List of Members

Chairman	Motoyasu Kamata	Professor Emeritus, The University of Tokyo
Members	Yukie Iino	Researcher, Consumer Lives Research Center, Japan Consumer's Association
	Tadayoshi Tanaka	General Manager, Technology Planning and Management Department, The Energy Conservation Center, Japan (Replaced by committee member Inoue from the second meeting)
	Mamoru Inoue	General Manager, Technology Planning and Management Department, The Energy Conservation Center, Japan (Joined from the second meeting)
	Shinya Okada	Deputy Chairman, Heat Pump Water Heater Committee, The Japan Refrigeration and Air Conditioning Industry Association
	Kiyoshi Saito	Professor, Faculty of Science and Engineering, Waseda University
	Masako Sugimoto	Director, Nippon Association of Consumer Specialists
	Hirofumi Daiguji	Associate Professor, Graduate School of Frontier Sciences, The University of Tokyo
	Koichi Takubo	Manager, Business Department, The Federation of Electric Power Companies of Japan
	Chiharu Murakoshi	Vice President, Jyukankyo Research Institute Inc.

Reference

Status Quo of Heat Pump Water Heaters

July 22, 2010

Ministry of Economy, Trade and Industry
Commerce and Information Policy Bureau
Information and Communication
Electronics Division

1. What is Heat Pump Water Heater?

- **Heat pump water heaters**
  - ✓ A collective name for water heaters using the principle of heat pump as in the case of air conditioners. They are considered as products excellent in energy saving performance. There are residential heat pump water heaters and commercial heat pump water heaters.

* The name “EcoCute” is a registered trade name of the Kansai Electric Power Co., Inc., which is used by many companies with the permission of said company.

■ Features

✓ The heat pump unit ((1) in the right figure) efficiently makes a large amount of hot water, and then it is stored (storage temperature at 65 to 90℃) in the hot water storage unit ((2) in the right figure). Hot water is served from the storage unit when it is used at baths, lavatories, kitchens, etc.

✓ Residential heat pump water heaters generally make hot water using less expensive nighttime electricity, so their electric bill is relatively low.

■ Refrigerant used

✓ Heat pump water heaters using HFC (fluorocarbon) as refrigerant are conventionally available in the market. However, those using carbon dioxide (CO_2) as refrigerant were developed in 2001, and the demands, especially for residential models, has been expanding. (Some commercial models are still using HFC.)

2. Types of Heat Pump Water Heaters (1)

- **Residential heat pump water heaters**
  - ✓ Residential heat pump water heaters are classified into several types according to their tank shape, capacity, function, etc. The capacity ranges from 370 to 460 L in case of products for standard households (4 family members) and from 150 to 200 L in case of compact tanks (for a single, 2 family members, etc.).

1. Types by tank shape and capacity


<Standard tank>


<Thin tank>


<Compact tank>


<All-in-one type>

2. Types by function

a. Full-auto type
Those equipped with functions of “automatic hot water filling”, “hot water adding”, “automatic heat-retention” and “reheating” for bath.

b. Auto (semi-auto) type
Those equipped with functions of “automatic hot water filling” and “hot water adding” for bath.

c. Hot water supply only type
Those designed only for hot water supply, so they fill a bath with hot water through a faucet.

d. Multifunction type
Those equipped with a floor heating function in addition to a hot water supply function for bath, lavatory, kitchen, etc.

3. Types of Heat Pump Water Heaters (2)

- **Commercial heat pump water heaters**
  Commercial heat pump water heaters are used in commercial facilities such as buildings, hotels, etc. Following types are available according to their scales and hot water amount used.

<For small scale buildings>

- ✓ Clinics, inns, small welfare facilities, etc.
- ✓ Restaurants, shops, etc.

<For large scale buildings>

- ✓ Hospitals, hotels, large welfare facilities
- ✓ Sports spa facilities, meal supply facilities, etc.

4. Shipping Quantity of Heat Pump Water Heaters (1) (Residential)

■ **Residential heat pump water heaters**

✓ Shipping quantity of residential heat pump water heaters started to rapidly increase in around year 2002 (*), making cumulative shipping quantity reach approximately 2.25 million units. Shipment quantity in FY2009 is 508 thousand units, and the market size remains at around 500 thousand units likewise in the previous year.

✓ Main manufacturers are the following 12 companies, and there are few imported products sold in the market.

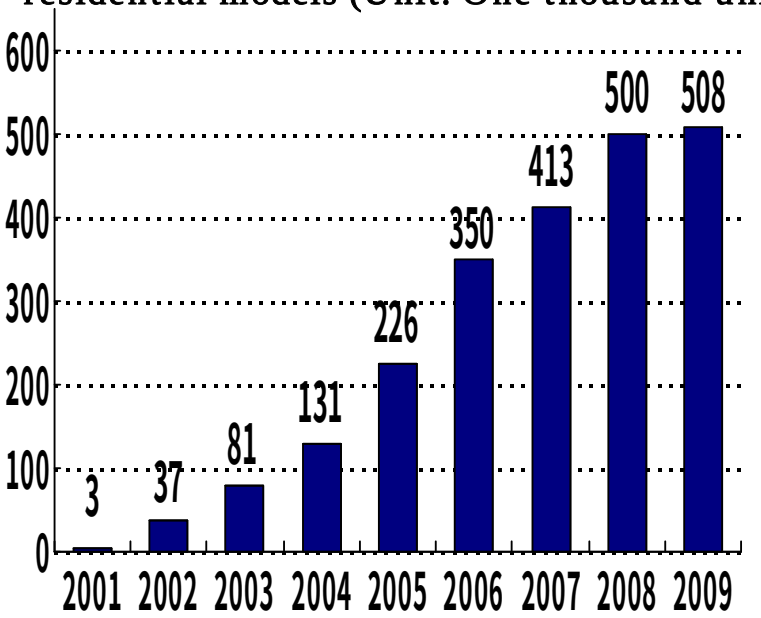
* A "subsidy system" in which the government bears part of the cost to install heat pump water heaters (CO_2 refrigerant) was implemented in FY2002. Since then, thanks to this subsidy system in part, the number of installed units has rapidly increased.

● **Main manufacturers of residential products**

Corona Corporation
Sanden Corporation
SANYO Electric Co., Ltd.
Daikin Industries, Ltd.
Choshu Industry Co., Ltd.
CHOFU SEISAKUSHO Co., Ltd.
DENSO Corporation
TOSHIBA CARRIER Corporation
Housetec Inc.
Panasonic Corporation
Hitachi Appliances, Inc.
Mitsubishi Electric Corporation

(In Japanese alphabetical order)

● **Transition of shipping quantity of residential models (Unit: One thousand units)**



Data provided by The Japan Refrigeration and Air Conditioning Industry Association

5. Shipping Quantity of Heat Pump Water Heaters (2) (Commercial)

■ **Commercial Heat Pump Water Heaters**

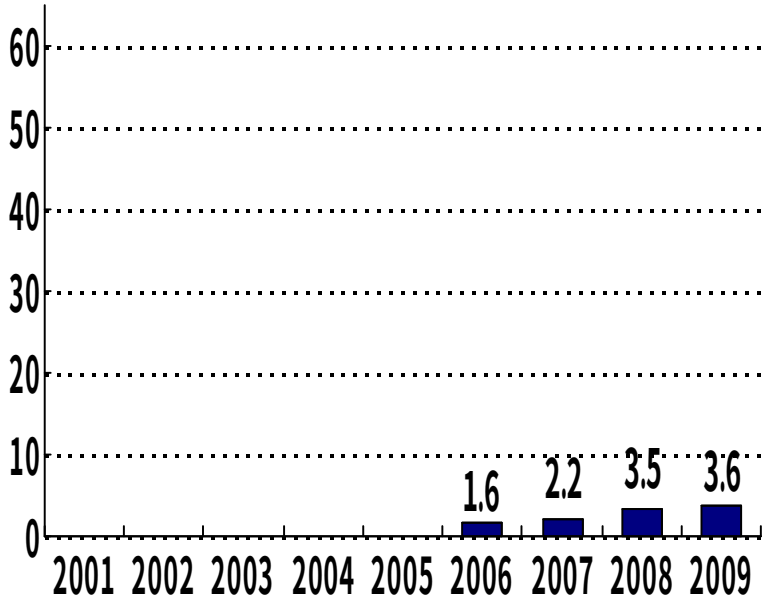
✓ Shipping quantity of commercial heat pump water heaters in FY2009 is 3.6 thousand units, and its cumulative shipping quantity is 10 thousand plus units. Its market size is small compared with that of residential models, occupying only less than 1% of the heat pump water heater market as a whole.

✓ Main manufacturers are the following companies, and there are few imported products.

● **Main manufacturers of commercial products**

Showa Manufacturing Co., Ltd.
Daikin Industries, Ltd.
DENSO Corporation
TOSHIBA CARRIER Corporation
Nihon Itomic Co., Ltd.
Panasonic Corporation
Hitachi Appliances, Inc.
MAYEKAWA MFG. Co., Ltd.
Mitsubishi Electric Corporation
(In Japanese alphabetical order)

● **Transition of shipping quantity, commercial (Unit: One thousand units)**



Data provided by The Japan Refrigeration and Air Conditioning Industry Association

6. Technology of Heat Pump Water Heaters (1)

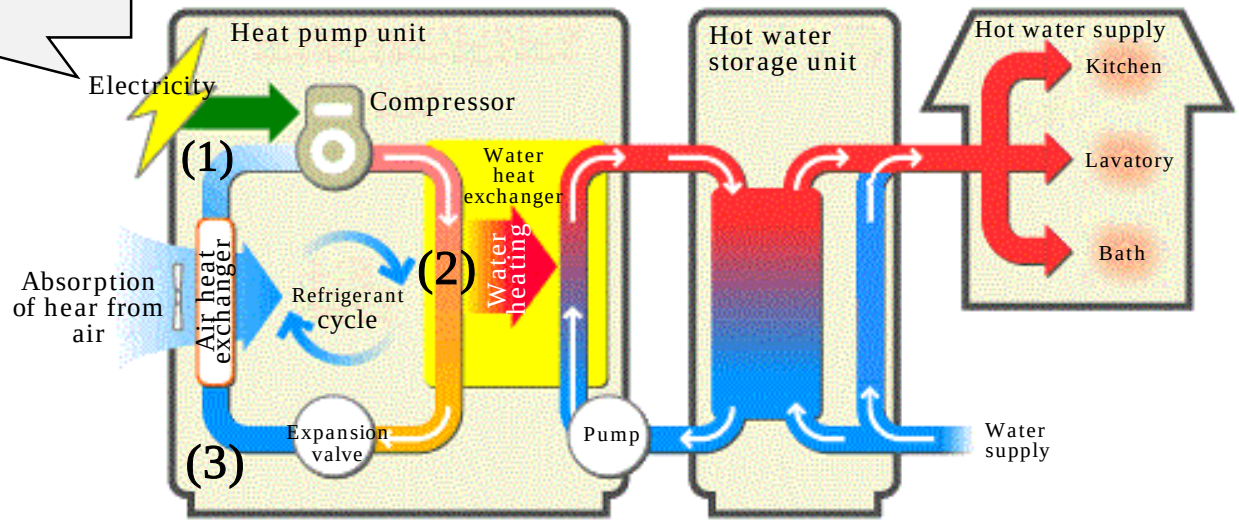
■ **Principle of making hot water**

Using the "principle of heat pump" which is also employed in air conditioners, heat pump water heaters make hot water through the compression-expansion cycle of refrigerant, store it in a hot water storage tank and supply it.

(1) A heat pump water heater makes its refrigerant to absorb heat from air through an "air heat exchanger" and compresses the refrigerant with a compressor to bring it into a high temperature and high pressure state. (2) Then, the heat of the refrigerant is transferred to water through a "water heat exchanger", and the produced hot water is stored in a hot water storage tank. (3) The refrigerant which lost heat is expanded by an expansion valve to bring it back to a low temperature and low pressure state again in which it can easily absorb heat from air. A heat pump water heater is a mechanism repeating this procedure.

•In a heat pump unit, hot water is made through heat exchange using the heat of air.

* Hot water stored in the hot water storage unit is kept hot and used according to the purpose of use.

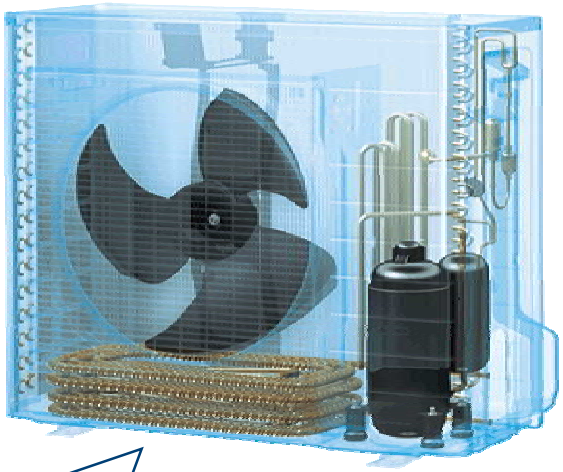


7. Technology of Heat Pump Water Heaters (2)

■ **Toward further energy saving**

To realize further energy saving, efficiency of every component is being enhanced.
(1) As for technologies of the heat pump side, efficiency improvement of heat exchangers, compressors, etc. is being worked on. (Figure (1) below shows an example of efficiency improvement made to a water heat exchanger.)
(2) As for technologies of the hot water storage unit side, improvement of thermal insulation performance by using vacuum thermal insulation materials, etc. is being worked on. (Figure (2) below shows an example of vacuum thermal insulation material.)

(1)

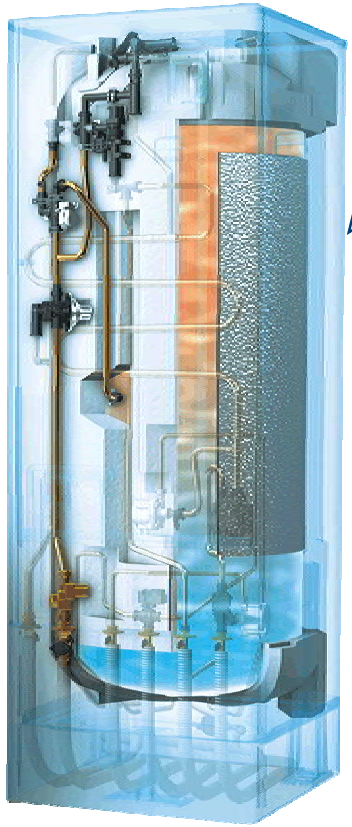


(Dimple refrigerant tube)

(Corrugated water tube)

<Water heat exchanger>
Pressure loss of refrigerant is reduced by taking advantage of the shape of refrigerant tubes and water tubes. Meanwhile, heat exchange efficiency is improved by expanding the heat exchange area.

(2)



(Vacuum thermal insulation material)

<Vacuum thermal insulation material>
Efficiency is improved by adopting vacuum thermal insulation materials whose thermal insulation performance is better than those of conventional glass wool or foamed polystyrene.