Survey on Heat Pump Diffusion Forecast

16 January 2015

Heat Pump and Thermal Storage Technology Center of Japan

Contents

1. Targets of this survey

In this survey, we surveyed promotion of heat pump utilization in the following fields and calculation of energy-saving effects thereof.

Residential use	・Residential heat-pump water heaters ・Residential heat-pump air conditioners
Commercial use	・Commercial heat-pump water heaters ・Highly efficient air conditioning heat pumps (Building multi split type air conditioners and central systems)
Industrial use	・Heat pumps for air conditioning ・Heating (hot water supply) heat-pump ・Heat pumps for low-temperature drying (lower than 100℃) ・Heat pumps at high temperatures of (higher than 100℃)
Agricultural use	・Agricultural heat pumps

In each application, trial calculations of an expected quantity of heat pumps to be introduced are made on a flow basis and on a stock basis. Then, the energy-saving effects through replacement from conventional equipment and improvement of equipment efficiency are calculated on a trial basis.

2. Residential water heaters

2.1 Concept of outlook

As for those households that have not introduced residential heat pump water heaters, we divided the market into a new house market and an existing house market for estimation. Moreover, we divided the existing buildings into detached houses and apartment houses, and further divided detached houses into the following three types according to the lot areas of houses:

- Urban Type I: Houses with a lot area of less than 75 m^2 and a building-to-land ratio of 40% or larger
- Urban Type II: Houses with a lot area of less than 150 m^2 and a building-to-land ratio of 40% or larger
- Average scale: Houses other than Urban Types I and II

For apartment houses, we divided them into owned houses and rented houses.

For new houses as well, we divided detached houses into three types according to their premises. In case of apartment houses, we divided them into owner-occupied houses and rented houses as is the case with the existing houses.

As for those households that have already introduced heat-pump water heaters, moreover, we assumed that such households introduce heat-pump water heaters again in renewal of their water heaters and estimated the quantity thereof.

We made four scenarios based on acquisition rates that are set in respective markets. Market segment classifications and estimation methods are summarized in Table 2-1. Future estimations were made by using the latest data on the market and the data on the recent introduction.

Table 2-1
Segment classifications of assumptions of residential heat-pump water heaters

<table>
<tr><th colspan="4">Segment (Unit of analysis)</th><th>Estimation methods of energy saving effect</th></tr>
<tr><td rowspan="10">Households that have not introduced heat-pump water heaters</td><td rowspan="5">Existing houses</td><td rowspan="3">Detached houses</td><td>Average scale</td><td rowspan="10">● On the assumption that heat-pump water heaters will be introduced when conventional types of equipment (oil or gas water heaters) are renewed, the quantity and energy-saving effect thereof are estimated.
● On the assumption that more efficient products will be introduced when heat-pump water heaters after replacement are renewed again, the cost reduction effects thereof are estimated.
● In consideration of the stock vintages with sale years, in addition to the number of units introduced, the energy-saving effects are estimated including those through replacement.</td></tr>
<tr><td>Urban Type I</td></tr>
<tr><td>Urban Type II</td></tr>
<tr><td rowspan="2">Apartment houses</td><td>Owned houses</td></tr>
<tr><td>Rented houses</td></tr>
<tr><td rowspan="5">New houses</td><td rowspan="3">Detached houses</td><td>Average scale</td></tr>
<tr><td>Urban Type I</td></tr>
<tr><td>Urban Type II</td></tr>
<tr><td rowspan="2">Apartment houses</td><td>Owner-occupied houses</td></tr>
<tr><td>Rented houses</td></tr>
<tr><td colspan="4">Households that have already introduced heat-pump water heaters</td><td>● On the assumption that heat-pump water heaters will be introduced again at the time of renewal, the quantity thereof is estimated.
● The energy-saving effects through efficiency improvement at the time of replacement are also included.</td></tr>
</table>

2.2 Confirmation of markets

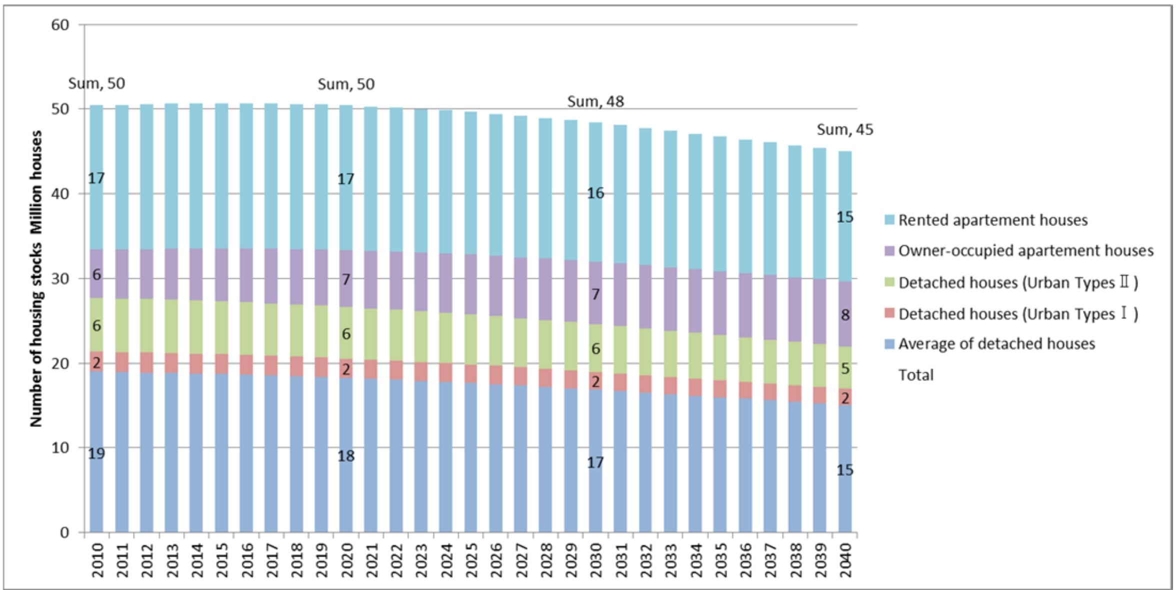
In respect of the existing house market and new house market, the following estimations were made.

2.2.1 Existing house market

As for the existing house market, estimations were made based on the number of housing stocks.

First, we estimated the number of principal households by age every five years in and after 2010 through 2040, and assumed that the housing stocks will also increase or decrease in proportion to the increase or decrease in the number of principal households. Then, we divided the housing stocks into detached houses and apartment houses. Detached houses were divided into Urban Types I and II, and apartment houses were divided into owner-occupied houses and rented houses. By making future estimation of ratios of detached houses and apartment houses based on the most recent trends, the housing stocks of residing households are organized in respective years (Fig. 2-1).

Urban Type I : Houses with a lot area of less than 75 m^2 and a building-to-land ratio of 40% or larger
Urban Type II : Houses with a lot area of less than 150 m^2 and a building-to-land ratio of 40% or larger
Average scale : Houses other than Urban Types I and II



Reference:"Future population estimates of Japan" National Institute of Population and Social Security Research
"National census" the Ministry of Internal Affairs and Communications

Figure 2-1 Changes in housing stocks (Residing households)

The market of water heaters for exiting houses was estimated by "replacement demand = existing housing stocks with residing households x incidence of replacement." The incidence of replacement of water heaters in existing houses is set at 6.27% per year based on the total quantity of water heaters sold in the existing house market over the past five years, including gas water heaters and others.

Based on the points mentioned above, we estimated the future outlook for replacement demand for water heaters in the existing house market as shown in Fig. 2-2. It can be considered that the existing house market itself reduces in proportion to the decrease in housing stocks.

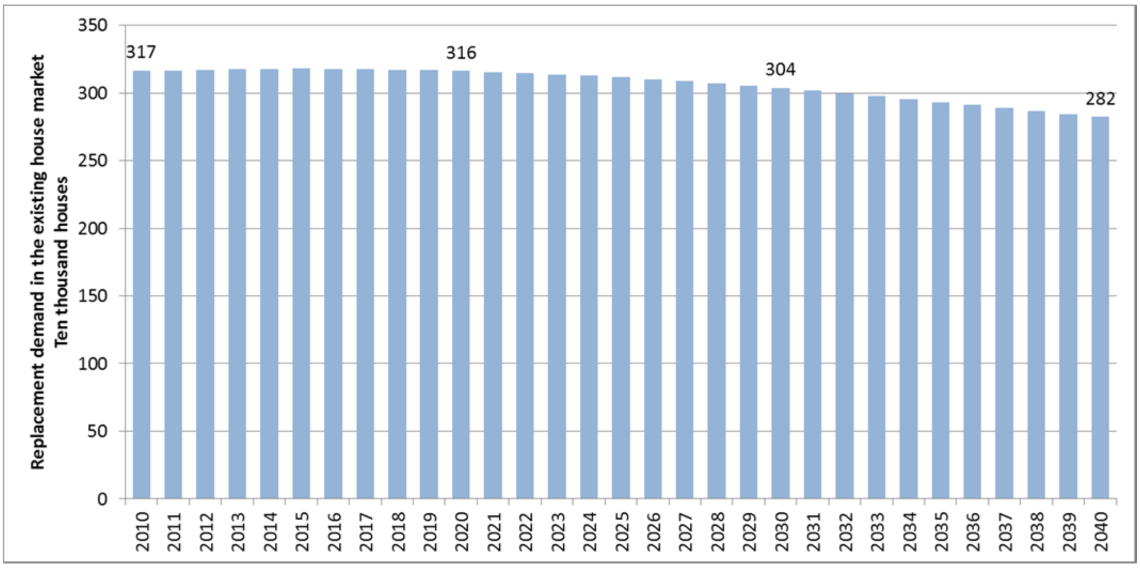


Figure 2-2

Outlook for replacement demand for water heaters in the existing house market

2.2.2 New house market

As for the new house market, the number of housing starts was estimated by the numerical expression in consideration of the number of housing stocks with no residing households such as follows;

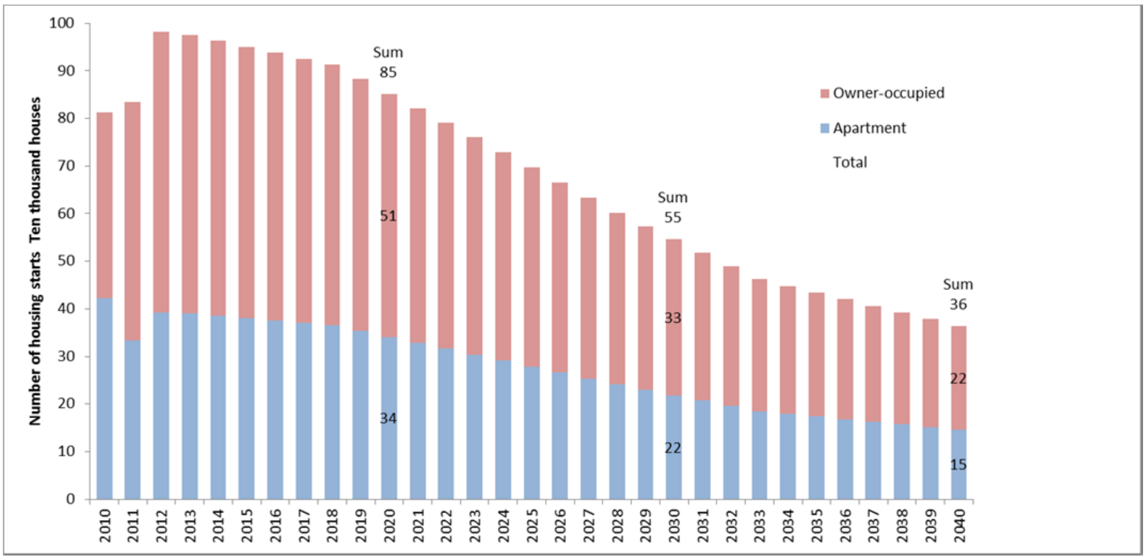
"Number of housing starts = increase or decrease in the number of households + increase or decrease in vacant houses + the number of houses reconstructed"

For estimation, the number of households, the number of houses reconstructed and a breakdown of detached houses and apartment houses were set and estimated based on publicly available data. As for the future outlook for vacant houses and others, the recent housing stocks with no residing households on footing are divided into:

i) Houses with temporary occupants only
ii) Vacant houses
iii) Houses under construction

Then, i) houses with temporary occupants only are set by laying, ii) vacant houses are set by supplementing with an approximate expression based on the past trends, and iii) houses under construction are set by linear interpolation (simple reduction) based on the past trends.

Based on the points mentioned above, the future outlook for the number of housing starts was estimated as shown in Fig. 2-3.



Reference:"Statistics of New house market of Japan" the Ministry of Land, Infrastructure, Transport and Tourism , "Population and household statistics"the Ministry of Internal Affairs and Communications

Figure 2-3 Outlook for the number of new housing starts

The outlook for the new house market and that for the existing house market are combined and the outlook for the entire water heater market including gas water heaters is shown in Fig. 2-4. The more heat-pump water heaters are introduced, the farther the market for replacement from gas or oil water heaters in the existing house market reduces. Therefore, to ensure the introduction quantity in the future, it is important to maintain the acquisition rate in the new house market, steadily implement replacement from heat-pump water heaters, and maintain and improve the acquisition rate in replacement in the existing house market.

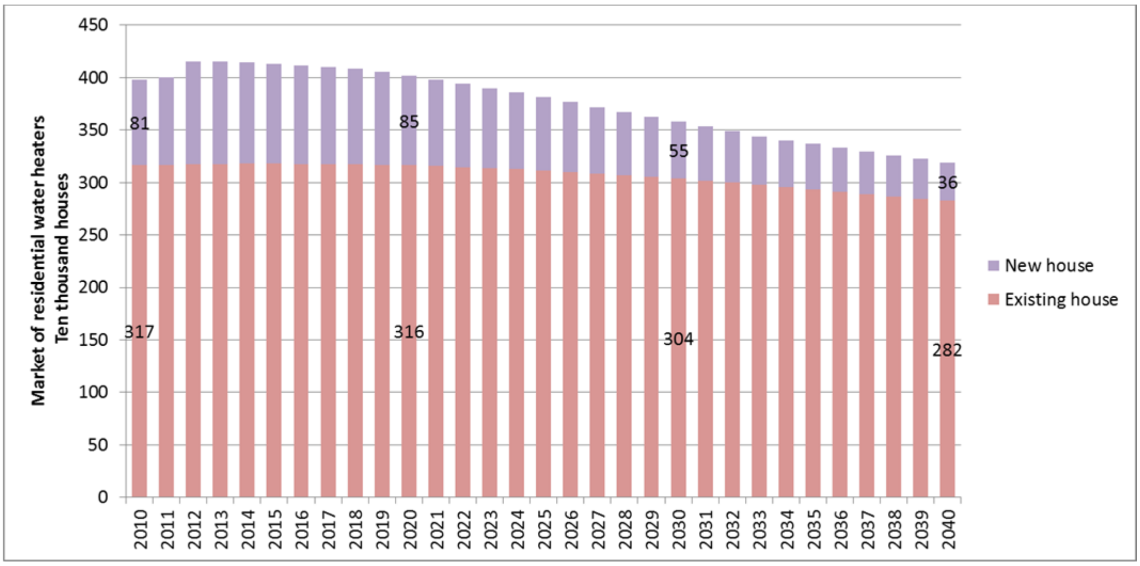


Figure 2-4 Outlook for the residential water heaters market

2.3 Estimation of introduction quantity

2.3.1 Concept of classification of target market

The respective markets are classified into the following three groups and the rates of introduction are estimated.

Table 2-2 Classification of target market for estimation of the introduction quantity

Classification of market	Concept
Renewal market	On the assumption that those users who have already introduced heat-pump water heaters introduce heat-pump water heaters again without fail, the introduction quantity was estimated. As mentioned earlier, the energy-saving effects of efficiency improvement by equipment replacement were also realized.
Main target market	On the assumption that main target is a half of detached and average-scale houses (new and existing houses) + detached and Urban Type II houses (new and existing houses), the introduction quantity was estimated.
Sub-target market	On the assumption that sub-target is a half of detached and Urban Type I houses (new and existing houses) + detached and Urban Type II houses (new and existing houses) + new apartment houses, the introduction quantity was estimated.

2.3.2 Results of recent introduction

The results of recent introduction of residential heat-pump water heaters were estimated by types of houses based on the estimated results of delivery by types of houses as shown in Fig. 2-5 and housing surveys.

The recent results have begun causing divergence from the outlook for stocks of 10 million units in use in FY2020 as the industry’s target, and the divergence began slightly increasing from around 2009. Moreover, after the Great East Japan Earthquake in 2011, the introduction quantity decreased on a flow basis, and the number of heat-pump water heaters actually delivered was only 460,000 units per year in 2013 compared with the assumption of 700,000 units per year. It is considered that this is because the introduction quantity temporarily declined due to the effect of restraint in activities of electric power companies to promote heat-pump water heaters after the earthquake disaster. The introduction quantity began recovering in FY2013. In and after FY2014, the introduction quantity is expected to increase because of efficiency improvement of heat-pump water heaters, promotion of energy-saving measures for houses, and resumption of activities of electric power companies to promote heat-pump water heaters.

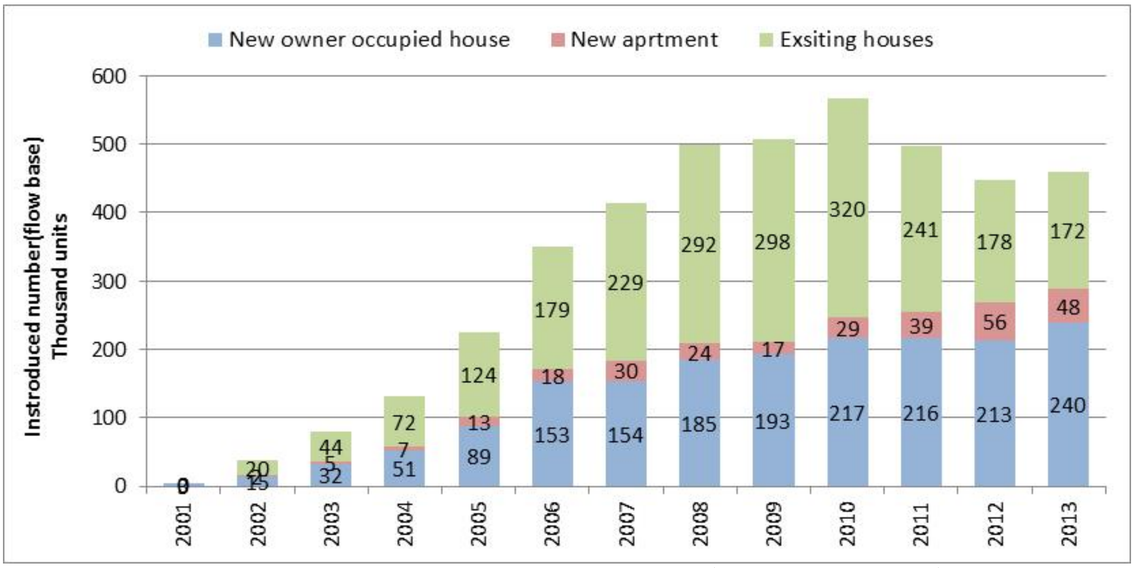


Figure 2-5　Estimated results of delivery (by types of houses)
of residential heat-pump water heaters

The recent results of introduction are further classified by target markets as shown in Fig. 2-6. The introduction quantity in the existing house market remained relatively stable with the passing years, while the introduction quantity in the new house market, particularly for existing detached houses, was significantly reduced in 2011 and 2012.

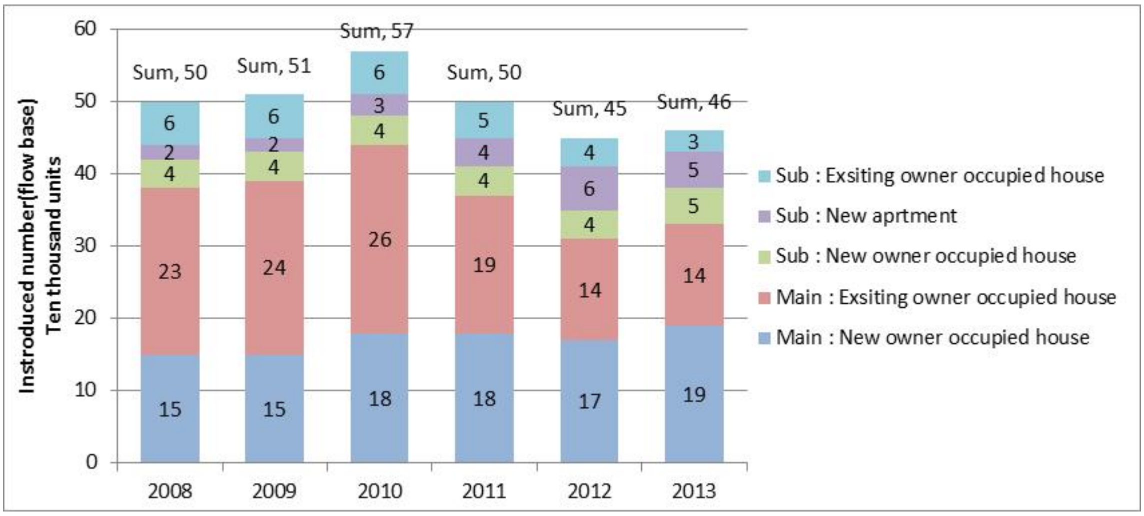


Figure 2-6　Estimated results of introduction (by target markets)
of residential heat-pump water heaters

2.3.3　　Concept of future estimates

As mentioned earlier, the introduction quantity in the future was estimated by setting the main market and sub-market and by setting the share in these markets.　For estimation, the introduction quantity was estimated in the following four cases:

1) Low-rank case: The present trends continue with no additional measures.
2) Middle-rank case: The market shares are improved by implementing measures such as subsidies for introduction.
3) High-rank case: The market shares are improved by promotion measures.
4) Reference case: The market itself is expanded by regulations on replacement and others.

	Present→2020	2020→2030	2030→2040
Low-rank	The market shares remain in the same trends.	The market shares are assumed to remain in the same trends.	The market shares are assumed to remain in the same trends.
Middle-rank	The market shares increase because of housing eco-points and others.	The effects of housing eco-points and others continue and the market shares remain in the same trends.	The effects of housing eco-points and others continue and the market shares remain in the same trends.
High-rank	The market shares increase because of registration of recommended equipment and others due to mandatory compliance with energy conservation standards.	The market shares increase because of commencement of mandatory compliance with energy conservation standards.	The effects of mandatory compliance with energy conservation standards continue and the market shares remain in the same trends.
Reference	The market shares increase because of housing eco-points and others.	The market of water heaters for the existing houses expands because of regulations on replacement.	The market of water heaters for the existing houses expands because of regulations on replacement.

Figure 2-7 Future scenario of residential heat-pump water heaters

2.3.4 Estimation results of introduction quantity

As the number of units delivered temporarily decreased because of the effect of restraint in activities of electric power companies to promote heat-pump water heaters after the Great East Japan Earthquake in 2011, it is difficult to achieve stocks of 10 million units in use in FY2020 only by continuing the present efforts.

In and after FY2014, however, the number of units to be introduced is expected to rise because of efficiency improvement of heat-pump water heaters, promotion of energy-saving measures for houses, and resumption of activities of electric power companies to promote heat-pump water heaters. Consequently it is possible to achieve stocks of 10 million units in FY2021 (or in FY2023 in middle- and low-rank cases and in reference case). As assumed in high-rank case, furthermore, it is also expected to achieve the stocks of 10 million units in FY2020, depending on additional measures to be taken by FY2020.

Moreover, if the government and private sectors continue to make their integrated efforts for proliferation of heat-pump water heater in and after FY2020, proliferation of about 16 million units is possible in FY2030 as seen in middle- and high-rank cases and reference case, excluding low-rank case.

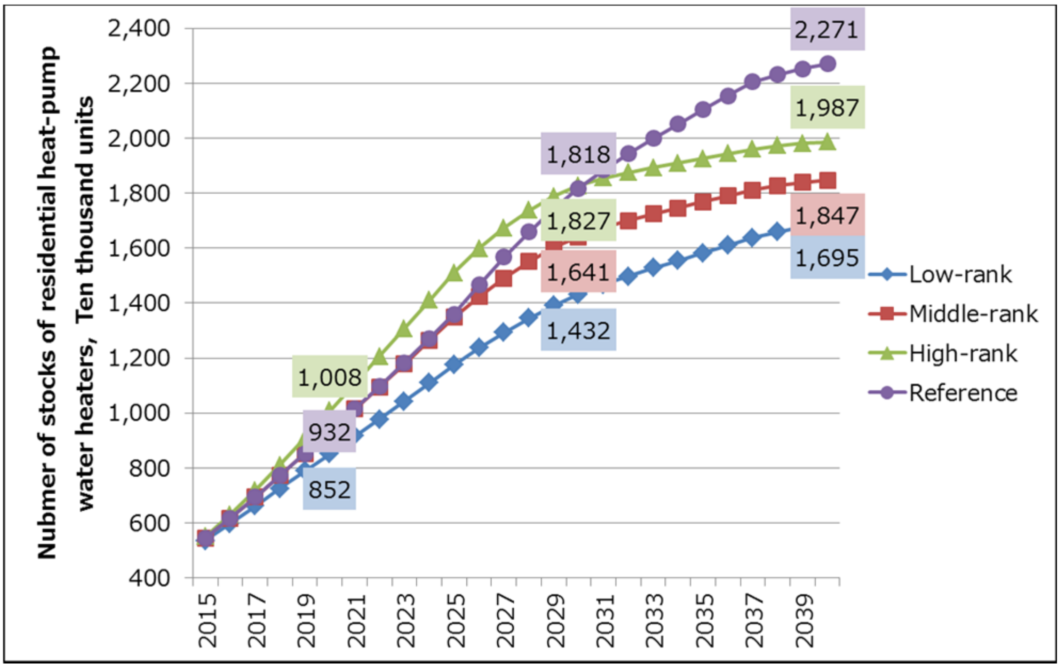


Figure 2-8
Estimation results of number of introduced units of residential heat-pump water heaters

2.4 Estimation of energy-saving effects

Based on the estimation results of introduction quantity, energy-saving effects were estimated by using the information about efficiency on heat pumps to be sold in respective fiscal years. In the case of replacement from heat-pump water heaters to heat-pump water heaters, the efficiency will also be improved on its flow basis. Therefore, it can be considered that energy conservation will also be achieved to a certain extent. Energy-saving effects were estimated including the effects through such replacement.

2.4.1 Preconditions

(1) Assumption of efficiency

The annual water heating and heat insulating efficiencies (JIS) of heat-pump water heaters are set as shown in Table 2-3. As for heat-pump water heaters, future assumed values are set by weighted average values based on the number of units delivered in 2010 by assuming the improvement rates for achieving the reference values of the Top Runner Program in FY2017 from the recent results by three types, general climate type, cold climate area type and small type and on the assumption that the efficiency becomes higher in the future. For reference, the efficiency of gas and oil water heaters replaced is set at 78% (HHV) on stock average in FY2012.

Table 2-3 Flow efficiency of various residential water heaters

	Year 2020	Year 2030	Year 2040
Heat-pump water heaters (annual water heating and heat insulating efficiencies (JIS))	3.29	3.61	3.94

(2) Assumption of water heating demand per household

Water heating demand per household is set at 18,000 MJ per unit a year as is the case with the assumption made by the Study Group on Promotion of Wide Use of CO2-refrigerant Heat-pump Water Heaters.

(3) Assumption of ratios of conventional water heaters
The ratios of conventional water heaters (based on the amount of hot water supplied) are set as follows as is the case with the Study Group on Promotion of Wide Use of CO2-refrigerant Heat-pump Water Heaters:

Gas water heaters: 75%, oil water heaters: 20%, and electric water heaters: 5%

2.4.2 Estimation results of energy-saving effects

The energy-saving effects that were estimated under these conditions are as follows. All of them represent the amount of energy saved from the starting point in 2012.

The effect of reduction in primary energy by proliferation of heat-pump water heaters is estimated to be 123 million GJ per year to 165 million GJ per year in 2030. The effect of reduction in primary energy by proliferation of heat-pump water heaters until 2012 amounted to as much as 31 million GJ per year. And, such energy-saving effect is expected to increase by about twice as much by 2020. In 2040, proliferation of about 18 million units is expected to realize energy savings of 170 million GJ to 205 million GJ per year.

Table 2-4 Number of stock and Estimation results of energy-saving effects (2012 base)

		2020	2030	2040
Number of stock (0.01 million units)	Low-rank	852	1,432	1,695
	Middle-rank	932	1,641	1,847
	High-rank	1,008	1,827	1,987
Effect of reduction in primary energy (Thousand GJ/Year)	Low-rank	49,344	122,749	170,246
	Middle-rank	57,230	145,194	188,300
	High-rank	64,701	164,984	204,889

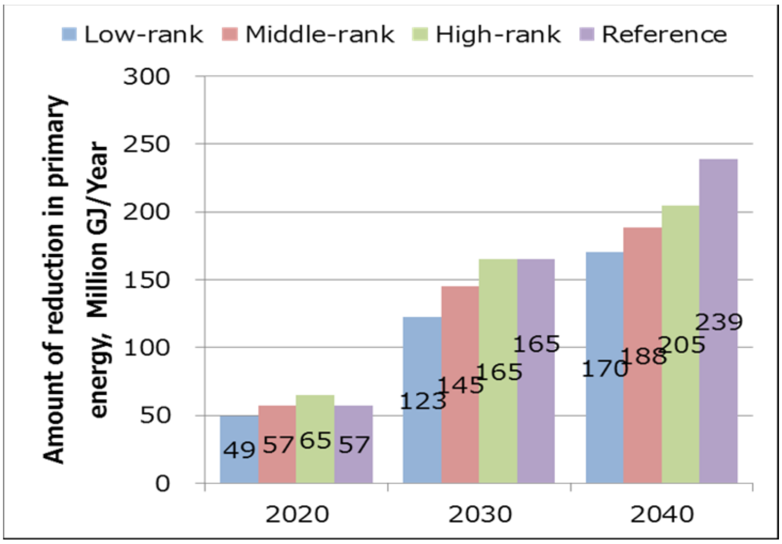


Figure 2-9　Results of the amount of reduction in primary energy（2012 base）

3. Residential air conditioners

3.1 Concept of outlook

The performance and efficiency of residential air conditioners have much been improved in recent years. It is considered possible to make a great contribution to energy conservation by encouraging the use of such highly efficient heat pumps for heating in houses. Though it is considered that utilization of air conditioners for heating have already been increasing, it is possible to further improve the utilization rate and promote energy conservation in residential sector by promoting proliferation and raising awareness of advantages of using air conditioners for residential heating.

Due to the application of the Top Runner Program and others, the efficiency of residential air conditioners has been improved, including cooling operation. It is considered possible to make a great contribution to residential energy conservation by encouraging replacement purchase from the aged existing air conditioners to the latest types.

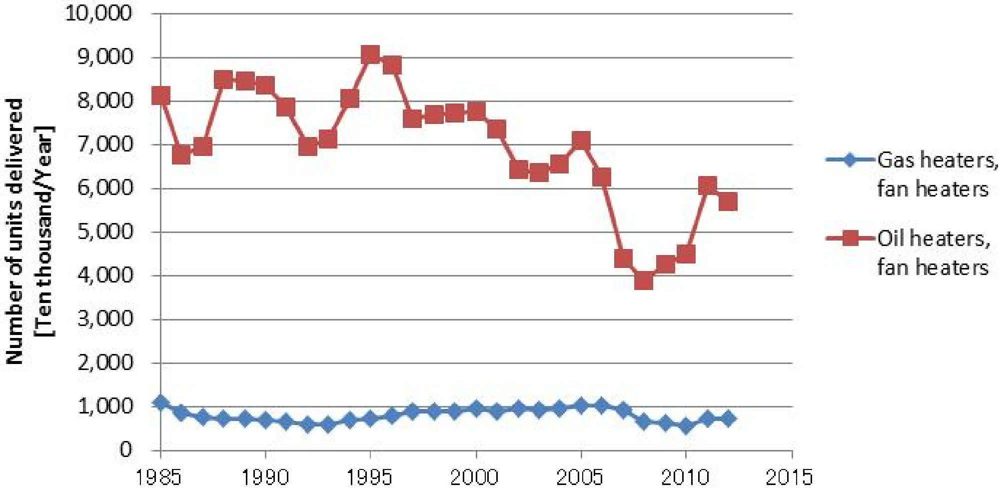
Here, we assumed some cases where the use of air conditioners for heating and replacement purchase from the existing air conditioners to the latest types are facilitated by the above-mentioned approaches, and calculated the energy-saving effects in these cases on a trial basis.

3.2 Confirmation of markets

3.2.1 Markets related to wider use of air conditioners for heating instead of combustion-type heating units

It can be thought that wider use of air conditioners for heating leads to reduction in conventional heating units such as residential fan heaters and oil or gas heaters. Here, we grasped the current status of the market of residential fan heaters and oil or gas heaters to be replaced by air conditioners based on the existing statistics.

For the quantity of conventional heating units actually delivered (flow) as shown in Fig. 3-1, the number of gas heating units has remained almost unchanged but that of oil heating units has been decreasing since the middle of the 1990s.



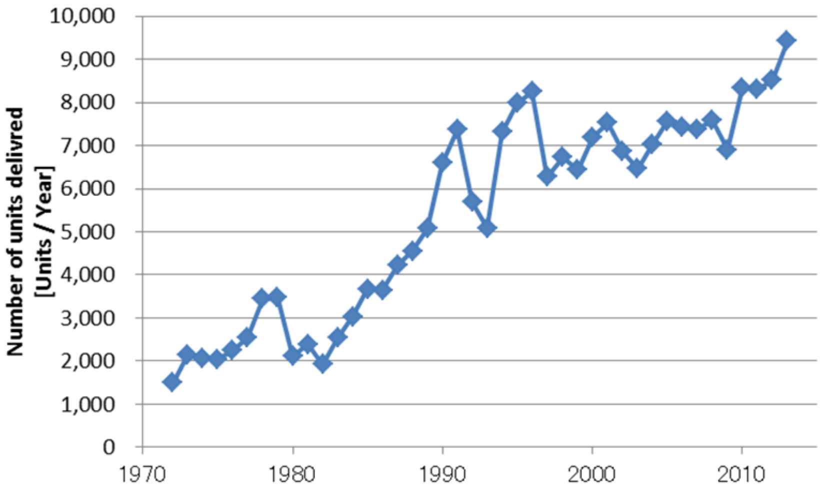
Reference; "Census of Manufacture""Yearbook of iron and steel, non-ferrous metals, fabricated metals statistic data" The Ministry of Economy, Trade and Industry

Figure 3-1 Changes in number of conventional heating units actually delivered

3.2.2 Markets related to replacement purchase from the existing air conditioners to the latest types

(1) Quantity of units actually delivered

The quantity of residential air conditioners actually delivered is set based on voluntary statistics of the Japan Refrigeration and Air Conditioning Industry Association (JRAIA). As shown in Fig. 3-2, the number of residential air conditioners delivered has continued to rise.



Reference;"National shipments of each product" JRAIA

Figure 3-2 Changes in number of residential air conditioners

Then, we estimated the stock amount of residential air conditioners by assuming survivor curves in proportion to the number of years passed after installation based on the data of annual quantity of delivery until the latest year that we organized such data as mentioned above. Here, the survivor curves are set to make the survival rates to be 50% at the time when the estimated average usage period of air conditioners is 11.8 years (according to 2011-2012 data from "Consumer Behavior Survey" of the Cabinet Office).

The estimation results of the recent stock amount of residential air conditioners, which are calculated based on the assumptions mentioned above, are shown in Fig. 3-3.

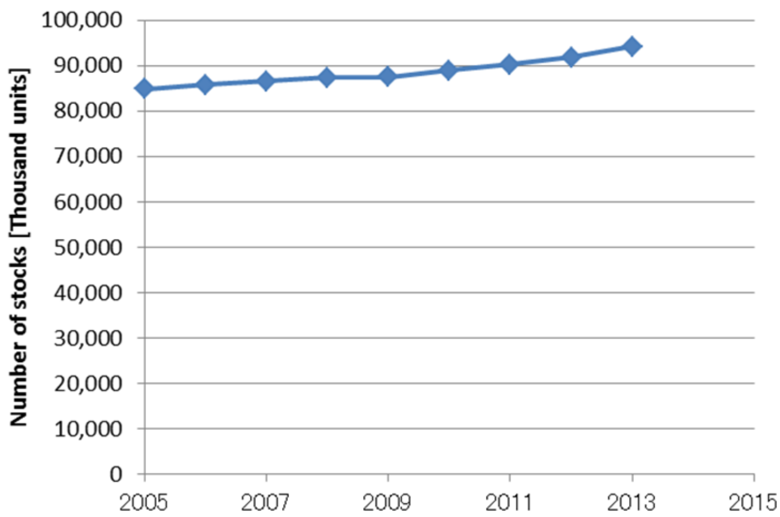


Figure 3-3 Estimation results of the stock amount of residential air conditioners

For reference, according to "Consumer Behavior Survey" of the Cabinet Office, the ownership rate of air conditioners in a family of two or more was 89% in 2010 and the number of air conditioners owned per household was about 2.6 units. Here, if the ownership rate of air conditioners in one-person households is assumed to be 89% and the number of air conditioners owned per household is assumed to be one unit, the stock amount of air conditioners is estimated to be 110 million units as there are 52 million households and the share of one-person households is 32% in 2010 according to "National Census."

This is consistent with the stock amount and order amount estimated by the quantity of delivery as adopted in this survey. Therefore, it is judged that the assumption of survivor curves of air conditioners set by this survey generally reflects the reality.

3.3 Estimation of introduction quantity

3.3.1 Introduction quantity related to wider use of air conditioners for heating instead of combustion-type heating units

If the use of residential air conditioners for heating increases, they will be used as alternatives to the existing heating units. Therefore, it is likely to lead the reduction of the number of fan heaters and oil or gas heaters to be delivered. Here, we set a future scenario of the replacement market by promotion of use of air conditioners for heating instead of conventional heating units as regarding "Wider use of residential air conditioners for heating = decrease in the number of fan heaters and oil or gas heaters to be delivered" on the assumption that one residential air conditioner is used for heating in proportion to a decrease by one fan heater or one oil or gas heater.

Specifically, we assumed a Business As Usual (BAU) case in terms of the quantity of conventional heating units to be delivered by taking into account that the quantity of conventional heating units delivered has been in a downward trend in recent years, and set three future scenarios in comparison with BAU.

Table 3-1 Scenarios of the promotion of use of air conditioners for heating instead of conventional heating units

Scenario	Details
Low-rank	The quantity of conventional heating units to be delivered changes linearly to the level of 75% compared with BAU case as of 2030 and then changes in the same trend as the future changes in the number of housing stocks.
Middle-rank	The quantity of conventional heating units to be delivered changes linearly to the level of 50% compared with BAU case as of 2030 and then changes in the same trend as the future changes in the number of housing stocks.
High-rank	The quantity of conventional heating units to be delivered changes linearly to the level of 25% compared with BAU case as of 2030 and then changes in the same trend as the future changes in the number of housing stocks.

※BAU: The same trend as that seen in the future changes in the number of housing stocks after 2013 based on the average value (5.5 million units/year) from 2008 to 2012

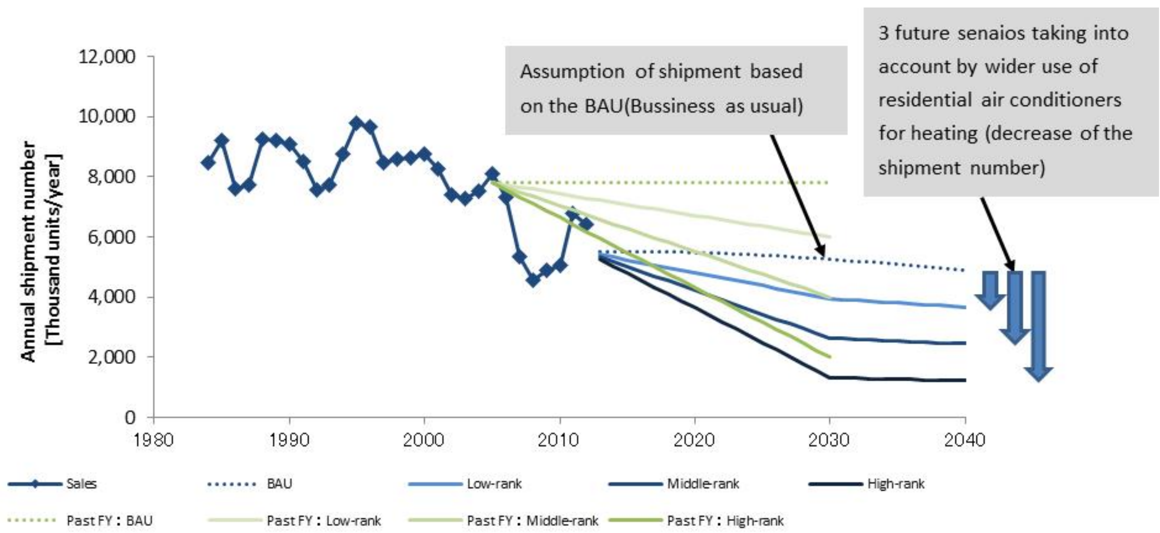


Figure3-4 Future scenarios of the quantity of conventional heating units delivered

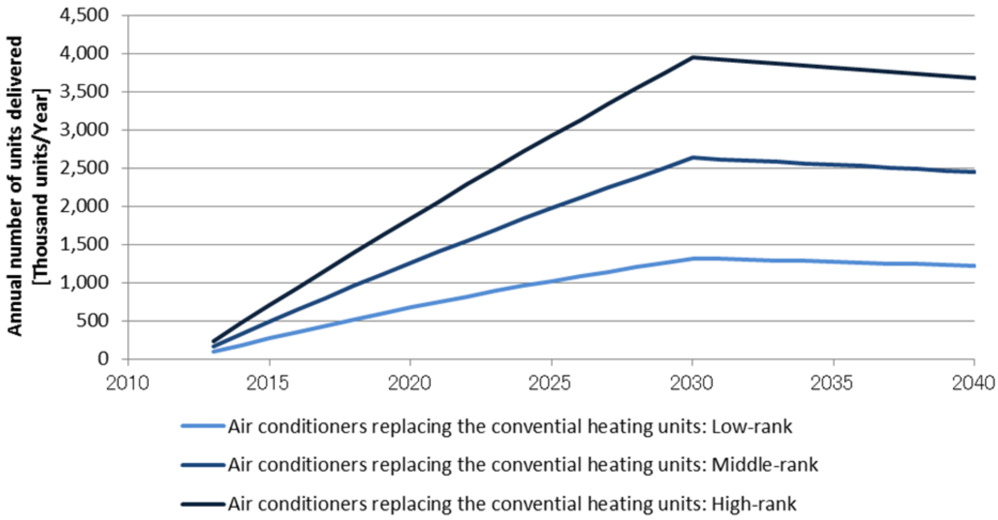


Figure 3-5
Future scenarios of flow of air conditioners replacing the conventional heating units

3.3.2 Introduction quantity related to replacement purchase from the existing air conditioners to the latest types

The quantity of stocks of air conditioners, excluding replacement from conventional heating units mentioned above, was assumed to remain unchanged in the future. Based on this assumption, we estimated the amount of replacement purchase from the existing air conditioners to the latest types by counting backward from the quantity of disposal which are estimated from survivor curves and the quantity of stocks.

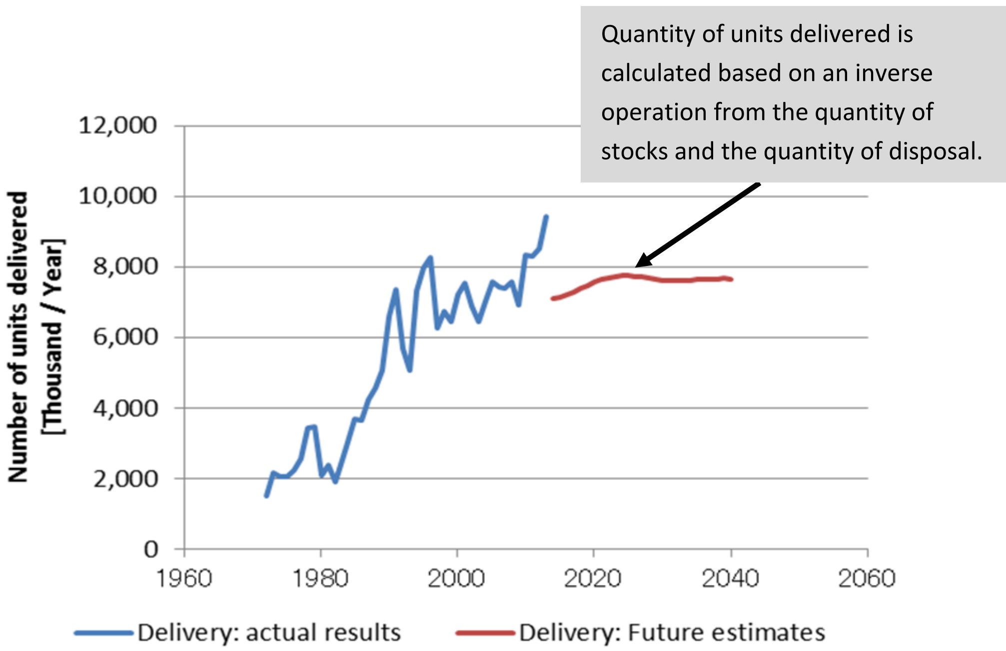


Figure 3-6 Future scenario of flow of air conditioners, excluding replacement from conventional heating units

As calculated above, the quantity of air conditioners to be proliferated in the future is as follows. The stocks of residential air conditioners are expected to increase from 92 million units in 2012 to 105 ～126 million units in 2030 as a result of promotion of use of air conditioners for heating instead of conventional heating units.

Table 3-2
Results of calculation of the quantity of stock of air conditioners thousand units

		Year 2012	Year 2020	Year 2030	Year 2040
By promotion of use of air conditioners for heating instead of gas or oil heaters	Low-rank	0	3,084	11,247	15,253
	Middle-rank	0	5,676	21,772	30,395
	High-rank	0	8,268	32,297	45,536
Existing air conditioners excluding replacement from conventional heating units		91,789	94,170	94,170	94,170

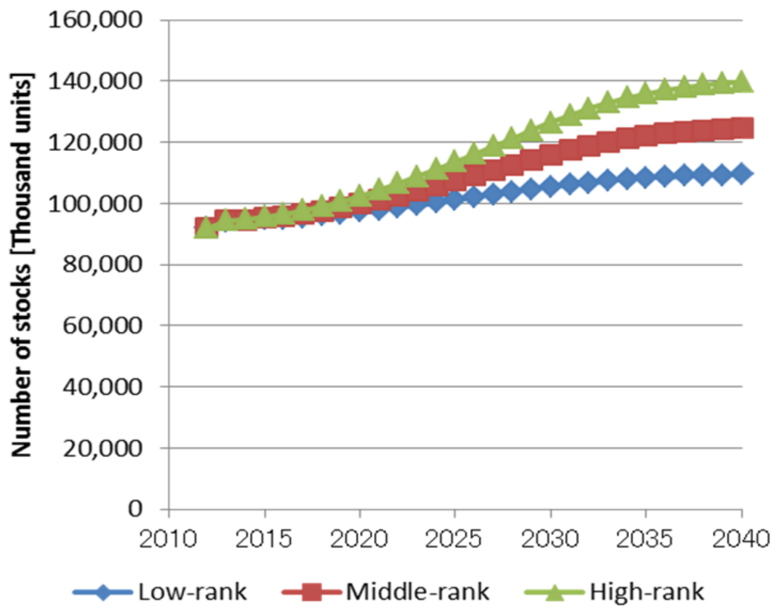


Figure 3-7 Results of calculation of the quantity of stock of air conditioners

3.4 Estimation of energy-saving effects

Based on the estimation results of introduction quantity, energy-saving effects were estimated by using the information about efficiency on heat pumps sold in respective fiscal years.

3.4.1 Preconditions

(1) Assumption of equipment efficiency

As for the efficiency of air conditioners, the average value of air conditioners delivered in 2010 (for an area of six to nine tatami mats) is APF 6.1. In consideration of this level, we assumed that APF 8.0 is achieved by air conditioners to be delivered in 2030 and APF 8.5 by air conditioners to be delivered in 2040. The efficiency of gas or oil heaters as conventional heating units is assumed to remain unchanged at 75% in the future

Table 3-3 Flow efficiency of residential air conditioners, gas or oil heaters

Appliances	Year 2010	Year 2020	Year 2030	Year 2040
Air conditioners	APF 6.1	APF 7.1	APF 8.0	APF 8.5
Gas or oil heaters	0.75	0.75	0.75	0.75

(2) Assumption of air-conditioning demand per household

According to "Handbook of Energy & Economic Statistics," the amount of energy consumed per household for cooling and heating in 2012 was 8.9 GJ for fossil fuels and 2.5 GJ for electric power. These values are multiplied by the equipment efficiencies of oil or gas heaters and air conditioners, respectively, to calculate their service demand, and the demand was divided by the number of units owned per household and the amount of heat supplied per unit of respective types of equipment was assumed as shown in the table below.

Table 3-4 Assumption of the amount of heat supplied per unit

Appliances	amount of heat supplied
Annual amount of heating per oil or gas heater: Amount of heating per air conditioner for promotion of use of air conditioners for heating instead of oil or gas heater	5.3GJ/Unit
Annual amount of cooling and heating per air conditioner: Amount of cooling and heating per air conditioner for replacement of the existing air conditioner	7.8GJ/Unit

3.4.2 Estimation results of energy-saving effects

The energy-saving effects as calculated based on the above description are shown below. The effects of reduction in primary energy use due to wider use of air conditioners for heating instead of gas or oil heaters and renewal of conventional air conditioners to the latest units are expected to be 140 to 247 PJ (3.61 million to 6.39 million kl) in 2030.

Table 3-5 Results of calculation of the amount of reductions of primary energy (starting point: 2012)

Unit: Thousand GJ/Year

		Year 2020	Year 2030	Year 2040
By promotion of use of air conditioners for heating instead of gas or oil heaters	Low-rank	15,125	57,391	80,045
	Middle-rank	27,841	111,142	159,517
	High-rank	40,556	164,892	238,989
Existing air conditioners excluding those replaced from conventional heating units		42,867	82,600	107,576

4. Water heaters for commercial use

4.1 Concept of outlook for proliferation of commercial heat-pump water heaters

4.1.1 Grasp of annual water heating demand by types of commercial water heaters

To assume the quantity of commercial heat-pump water heaters to be proliferated in the future, first of all, we organized total floor areas by applications in business fields and also organized breakdowns of total floor areas by scales of buildings and detailed applications.
We also estimated the quantity of total floor area stocks by classifying applications into "cold climate areas" and "general areas." Cold climate areas are defined below. Based on the data of total floor areas by prefectures, we calculated and estimated the ratios of total floor areas of "cold climate areas and general areas" by applications.

【Definitions of cold climate areas and general areas】

Cold climate areas: Hokkaido, Tohoku District (Aomori Prefecture, Iwate Prefecture, Akita Prefecture, Yamagata Prefecture and Fukushima Prefecture, Hokuriku District (Niigata Prefecture, Toyama Prefecture, Ishikawa Prefecture and Fukui Prefecture)

General areas: Areas other than those mentioned above

Then, we estimated the water heating demand in business fields by using the intensities of annual water heating demand per total floor area by industry and scale based on the data of total floor areas.

Table 4-1　Setting of the water heating demand by industry and scale

		Total floor areas (Million ㎡)			Hot water supply unit	Hot water supply unit	Annual water heating demand (Thousand GJ/Year)		
		Total	General areas	Cold climate areas	(Mcal/㎡・Year)	(MJ/㎡・Year)	Total	General areas	Cold climate areas
Offices		482	422	60	—	—	10,106	8,840	1,267
	699 ㎡ or less	161	140	20	2.2	9.2	1,478	1,293	185
	700 - 2,999 ㎡	120	105	15	2.2	9.2	1,107	968	139
	3,000 - 9,999 ㎡	81	71	10	2.2	9.2	750	656	94
	10,000 ㎡ or more	120	105	15	13.5	56.5	6,771	5,922	849
Stores		470	398	73	—	—	45,289	38,309	6,981
	699 ㎡ or less	130	110	20	23	96.3	12,506	10,578	1,928
	700 - 2,999 ㎡	110	93	17	23	96.3	10,544	8,918	1,625
	3,000 - 9,999 ㎡	71	60	11	23	96.3	6,854	5,798	1,056
	10,000 ㎡ or more	160	135	25	23	96.3	15,386	13,014	2,371
Restaurants and bars		66	55	10	135	565	37,071	31,357	5,714
Schools		363	296	67	—	—	16,670	13,617	3,053
	Nursery schools	16	13	3	45.1	188.8	2,998	2,412	586
	Kindergartens	13	11	2	2.9	12.1	163	139	25
	Elementary, junior high and high schools	255	204	51	8.9	37.3	9,482	7,590	1,892
	Universities	60	52	8	13.2	55.3	3,308	2,881	427
	Others schools	19	16	3	8.9	37.3	718	595	123
Hotels		92	74	19	—	—	30,943	24,685	6,258
	699 ㎡ or less	25	20	5	80	335	8,400	6,701	1,699
	700 - 2,999 ㎡	26	21	5	80	335	8,728	6,963	1,765
	3,000 - 9,999 ㎡	21	16	4	80	335	6,906	5,509	1,397
	10,000 ㎡ or more	21	16	4	80	335	6,909	5,512	1,397
Hospitals		111	88	22	—	—	37,105	29,632	7,473
	Clinics	29	24	5	80	335	9,860	8,059	1,801
	Hospitals	81	64	17	80	335	27,245	21,572	5,672
Others		251	200	51	—	—	36,642	29,231	7,410
	Welfare facilities	32	25	6	53	222	7,084	5,652	1,433
	Beauty and hair dressing services	15	12	3	120	502	7,373	5,882	1,491
	Sport facilities	4,286 places	3,419 places	867 places	875Gcal/place	3,663GJ/place	15,699	12,524	3,175
	Golf courses	8	7	2	160	670	5,566	4,440	1,126
	Theaters, amusement places	36	29	7	1.2	5.0	180	144	36
	Others than the above	147	117	30	1.2	5.0	740	590	150
Total		1,835	1,533	302		—	213,826.0	175,670	38,156

Reference;"The Energy Data and Modelling Center" and others

4.1.2 Assumption of upper limits on the number of commercial heat-pump water heaters to be introduced

It is not necessarily possible to introduce commercial heat-pump water heaters in all commercial buildings. Pros and cons of introduction are depending on applications and scales of buildings. Here, as shown in the table below, we judged the suitability of introduction upon grasping typical hot water supply systems now in use by applications and scales of buildings, and assumed the annual operation time of heat-pump water heaters by applications and scales of buildings.

		Assessment of suitability of introduction based on the current status of the existing hot water supply systems	Suitability of introduction of HP water heater
Offices		Hot water is mainly required and used in lavatories and office kitchens. In the past, there were cases where boilers and hot water supply pipes were installed in buildings. At present, however, as small water heaters or electric water heaters are usually installed at places where hot water is required in many cases, it is often difficult to introduce heat-pump water heaters. But, in the case of large buildings with a total floor area of more than 10,000 m^2, restaurants and bars are tenanted in many cases, and heat-pump water heaters can be introduced.	
	699 ㎡ or less		△
	700-2,999 ㎡		△
	3,000-9,999 ㎡		△
	10,000 ㎡ or more		○
Stores		As is the case with offices, hot water is mainly required and used in lavatories and office kitchens in the case of stores and hot water is mainly supplied at local points. Therefore, it is often difficult to introduce heat-pump water heaters. However, in the case of large-scale stores and shopping malls, restaurants and bars are tenanted in many cases, and heat-pump water heaters can be introduced.	
	699 ㎡ or less		△
	700-2,999 ㎡		△
	3,000-9,999 ㎡		△
	10,000 ㎡ or more		○
Restaurants and bars		Hot water is required mainly in kitchens and gas water heaters or other heaters are used. As is the case with residential types, hot water demand can be met by once-through-type heat-pump water supply systems.	○
Schools		Nursery schools always have kitchen equipment and a high demand for hot water. In the case of elementary, junior high and high schools, hot water demand is generated from those schools with meal preparation facilities. In the case of universities, hot water is required in cafeterias and gymnasia for shower rooms and swimming pools in some cases. In the case of kindergartens and other schools, there is little demand for hot water and hot water is required mainly in lavatories.	
	Nursery schools		○
	Kindergartens		△
	Elementary, junior high and high schools		○
	Universities		○
	Other schools		△
Hotels		In any scale, a large amount of hot water is required in lavatories, shower rooms, communal bathrooms and restaurants. Such hot water demand is basically met fully by central hot water supply systems (circulation types) that have hot water boilers and hot water tanks, and heat-pump water heaters can be introduced. In the case of large-scale city hotels, hot water is often used in kitchens for sterilization and drying and steam is used in linen room. And, steam boilers are used as heat sources in many cases.	
	699 ㎡ or less		○
	700-2,999 ㎡		○
	3,000-9,999 ㎡		○

<table>
<tr><td></td><td>10,000 m^2
or more</td><td>At present, it is difficult to introduce heat-pump water heaters for renewal in such cases. However, as linen services are increasingly outsourced and electric equipment are widely used to sterilize and dry tableware, the demand for hot water in such hotels can be met by heat-pump water heaters in the future. As the demand for hot water in large city hotels is basically large, heat-pump water heaters have size problems and others, but it is considered possible to make them suitable to all hotels in the future by downsizing them.</td><td>○</td></tr>
<tr><td colspan="2">Hospitals</td><td rowspan="3">Hot water is required at many places in buildings such as lavatories, shower rooms and bathrooms, and such demand is met fully by central hot water supply systems (circulation types) that have hot water boilers and hot water tanks in many cases. Clinics have instantaneous gas water heaters in many cases. In any case, heat-pump water heaters can be introduced. With regard to large-scale hospitals, steam boilers are used in some cases as steam is required for sterilization. In recent years, however, the use of steam tends to be disliked and sterilizers are used at individual points in many cases. Therefore, heat-pump water heaters can be introduced in large-scale hospitals as well.</td><td></td></tr>
<tr><td></td><td>Clinics</td><td>○</td></tr>
<tr><td></td><td>Hospitals</td><td>○</td></tr>
<tr><td colspan="2">Others</td><td rowspan="2">Hot water is required in kitchens, bathrooms and private rooms. Basically, such demand is met fully by central hot water supply systems (circulation types) that have hot water boilers and hot water tanks. In kitchens, water heaters are separately installed in many cases. In any case, heat-pump water heaters can be introduced.</td><td></td></tr>
<tr><td></td><td>Welfare facilities</td><td>○</td></tr>
<tr><td></td><td>Beauty and hair dressing services</td><td>A large amount of hot water is required at shampoo basins. As it is largely needed to keep hot water at a constant temperature and pressure, hot water boilers are often used for beauty and hair dressing services. It is easy to apply heat-pump water heaters as the temperature of hot water from their tanks is constant.</td><td>○</td></tr>
<tr><td></td><td>Sport facilities</td><td rowspan="2">Hot water is required at shower rooms, lavatories and heated swimming pools. Basically, such demand is met by central hot water supply systems (circulation types) that use hot water boilers. Heating on the poolside is provided by hot water from hot water tanks in many cases. At present, sports facilities are one of the typical applications for which many heat-pump water heaters are introduced.</td><td>○</td></tr>
<tr><td></td><td>Golf courses</td><td>○</td></tr>
<tr><td></td><td>Theaters,
Amusement places</td><td>Demand for hot water is generated at many places such as kitchens, lavatories and shower rooms. Hot water is also used for heating in bathrooms. Basically, such demand is met fully by central hot water supply systems (circulation types) that have hot water boilers and hot water tanks. Heat-pump water heaters can be introduced.</td><td>△</td></tr>
<tr><td></td><td>Others than the above</td><td>In building other than those mentioned above, hot water is required mainly in lavatories and office kitchens and hot water is supplied mainly at local points. Therefore, it is considered difficult to introduce heat-pump water heaters in many cases.</td><td>△</td></tr>
</table>

(1) Users whose introduction appropriateness is “ ○ ”

Those applications of which introduction appropriateness is “ ○ ” are assumed as buildings where the present commercial heat-pump water heaters will come into wider use. However, proliferation in cold climate areas is likely to be slower than that in general areas. The proliferation of commercial heat pumps in general areas is set to begin in 2002, while that in cold climate areas is set to start in 2014.

In respect of the scale of buildings, the output of heat pumps to be introduced in small-scale buildings such as restaurants and bars and the output of heat pumps to be introduced in large-scale buildings such as hotels and hospitals are different. Here, it is assumed that a 4.5-kW type commercial heat-pump water heater is introduced in a small building where the hot water demand is small and a 22-kW type commercial heat-pump water heater is introduced in a large building where hot water demand is large, and single unit capacities are assumed for each building category.

Consequently, the number of 4.5-kW type commercial heat-pump water heaters that can be introduced in buildings whose introduction appropriateness is “ ○ ” is estimated to be 5,022 thousand units, and that of 22-kW type is estimated to be 1,097 thousand units. On a 22-kW basis, the number is equivalent to 2,124 thousand units.

(2) Users whose introduction appropriateness is “△”

As for those applications of which introduction appropriateness is “△,” hot water is used at many local points. So, it is difficult for the present heat-pump water heaters to cope with them. At present, however, the development of “downsized” heat pumps mainly for household use is underway. In the future, it is likely to commercialize those heat-pump water heaters that can be installed at local points such as places under sinks. Here, it is assumed that those types that can supply hot water at local points with a heating capacity of about 1 kW are introduced in buildings whose introduction appropriateness is “△” in and after 2014.

As a result, the number of 1-kW type commercial heat-pump water heaters that can be introduced in buildings whose introduction appropriateness is “△” is estimated to be 3,053 thousand units. On a 22-kW basis, the number is equivalent to 139 thousand units.

Table 4-2 Introduction appropriateness of commercial heat-pump water heaters

Applications of which introduction appropriateness is "○"	・Timing of proliferation is different between general areas and cold climate areas. General areas: Commercial heat-pump water heaters have been gradually introduced since 2002. Cold climate areas: Introduction started in 2014. ・It is assumed that either "4.5-kW" type or "22-kW" type is introduced in proportion to the scale of buildings.
Applications of which introduction appropriateness is "△"	It is assumed that small heat-pump water heaters (with a heating capacity of about 1 kW) that can supply hot water at local points are introduced in and after 2014.

4.1.3 Assumption of proliferation curve of commercial heat-pump water heaters

The most recent numbers of commercial heat-pump water heaters delivered are shown in Fig. 4-1. The number of commercial heat-pump water heaters delivered at an early stage of proliferation slowly increased until FY2011 and then decreased again in FY2012 and FY2013.

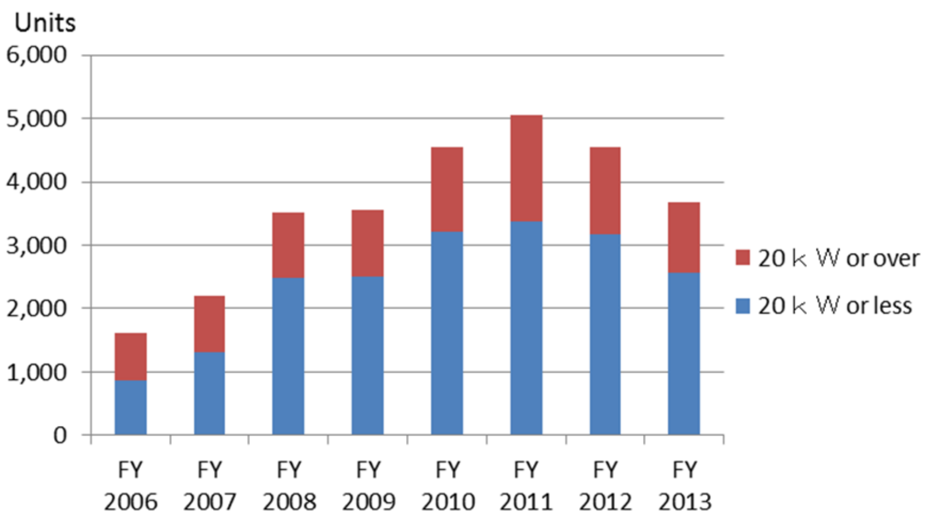


Figure 4-1 Actual numbers of introduction of commercial heat-pump water heaters delivered

In setting the proliferation curves of commercial heat-pump water heaters, the concept of logistic curves was used. Here, it was assumed that the introduction flow changes in accordance with the logistic curve shown in Fig. 4-2, which is approximated based on the actual introduction of similar equipment.

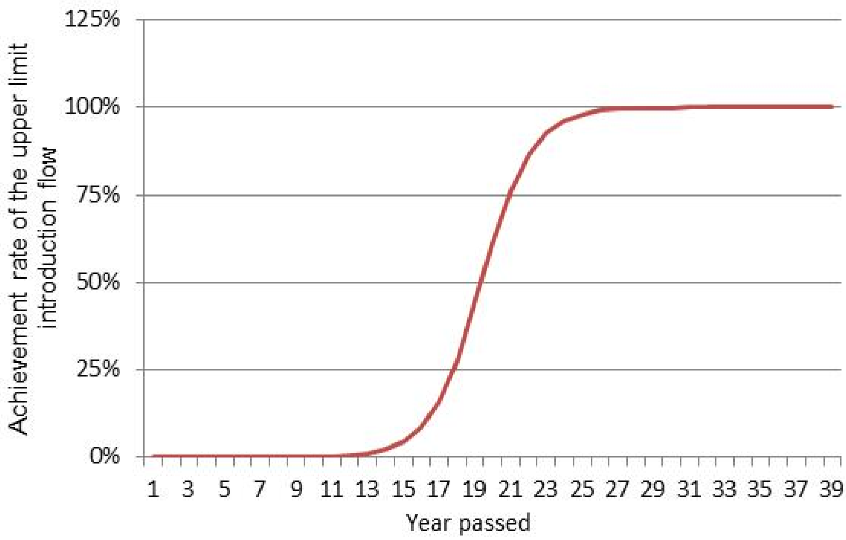


Figure 4-2 Assumption of the proliferation curves of commercial heat-pump water heaters

4.2 Estimation of introduction quantity of commercial heat-pump water heaters

The upper limit on the number of units to be introduced as specified above is a potential in the case where the introduction of commercial heat-pump water heaters is promoted to the greatest extent possible. In reality, however, it is difficult to introduce the upper-limit number of units due to various conditions. Here, we set several cases in proportion to the ratio of actual introduction to the potential, i.e., high-rank case (actualization rate is 70%), middle-rank case (50%) and low-rank case (30%).

4.2.1 Estimation of introduction quantity (flow basis) of commercial heat-pump water heaters

The numbers of units to be introduced (flow basis) in the middle-rank case are shown in the table below by area and capacity.

The introduction of units for general areas started in 2002 but remained slows for a while. The introduction is expected to begin accelerating after about 20 years later in 2020, reach the peak in around 2030 and remain almost unchanged until 2040.

On the other hand, the introduction of units for cold climate areas and 1-kW units is assumed to start in 2014. As the proliferation curve does not start up in the first 10 years, the number of units to be introduced in 2020 is still at a low level. The number of units to be introduced has started increasing in 2030 and sufficient proliferation is expected in as late as 2040.

Table 4-3 Comparison of numbers of the flow of units to be introduced by area and capacity (middle-rank case)

Units: Thousand

	2020	2030	2040
22kW (General areas)	12.4	44.6	44.7
22kW (Cold climate areas)	0.0	0.9	10.1
4.5kW (General areas)	57.5	206.7	207.2
4.5kW (Cold climate areas)	0.0	3.8	43.6
1kW	0.0	13.1	151.2
Total	**69.9**	**269.1**	**456.9**

Also, the changes in capacity of heat-pump water heaters to be introduced (flow basis) by area and capacity in the middle-rank case are shown in Fig. 4-3. As mentioned earlier, the proliferation of units for general areas is set to start in 2002 and that for cold climate areas and 1-kW units in 2014. Consequently, it can be seen that the proliferation of units for cold climate areas and that of 1-kW units come late in and after the 2030s. For reference, the period from 2006 to 2013 is based on the aforesaid actual value of commercial heat-pump water heaters introduced and the period in and after 2014 is linked to estimated values.

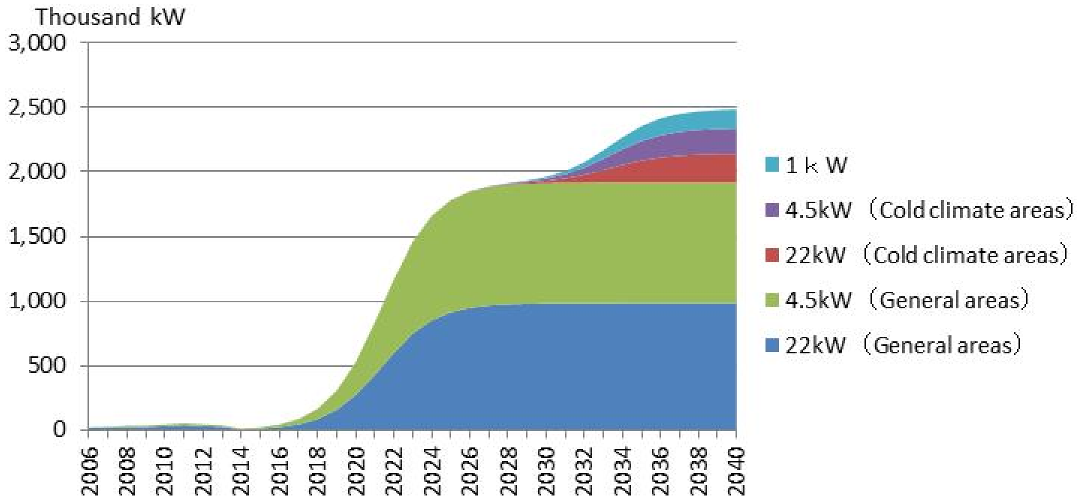


Figure 4-3 Comparison of capacities of the flow of units to be introduced by area and capacity (middle-rank case)

4.2.2 Estimation of introduction quantity (stock basis) of commercial heat-pump water heaters

The numbers of units to be introduced (stock basis) in the middle-rank case are shown in the table below by area and capacity. In stocks as well, units for general areas drive the introduction quantity ahead. However, the point that stocks can be expected to grow from the 2030s through the 2040s is different from flows.

In response to a rapid increase in flows in the 2030s, the introduction quantity of units for cold climate areas and 1-kW units is expected to increase from the 2030s through the 2040s.

Table 4-4 Comparison of numbers of the stock of units to be introduced by area and capacity (middle-rank case)

Units: Thousand

	2020	2030	2040
22kW (General areas)	31.5	362.8	468.2
22kW (Cold climate areas)	0.0	1.8	68.1
4.5kW (General areas)	135.0	1,679.7	2,168.0
4.5kW (Cold climate areas)	0.0	7.6	293.9
1ｋW	0.0	26.5	1,019.8
Total	**166.5**	**2078.3**	**4,018.1**

Also, the changes in capacity of heat-pump water heaters to be introduced (stock basis) by area and capacity in the middle-rank case are shown in the figure below. In this case, the period from 2006 to 2013 is also based on the accumulated amount of the aforesaid actual values (flows) of commercial heat-pump water heaters introduced and the period in and after 2014 is linked to estimated values.

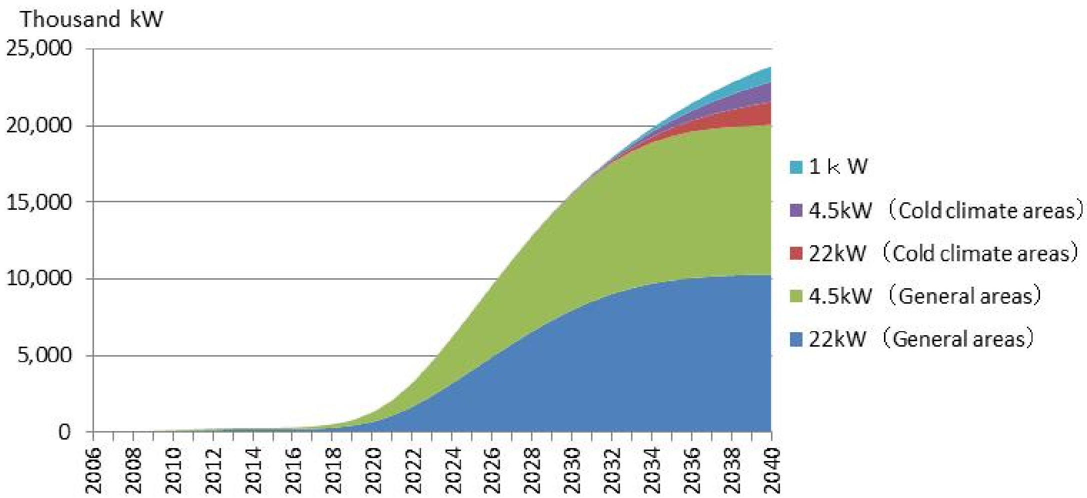


Figure 4-4 Comparison of capacities of the stock of units to be introduced by area and capacity (middle-rank case)

4.3 Energy-saving effects of commercial heat-pump water heaters

4.3.1 Preconditions

The energy-saving effects of replacement from conventional boilers to heat-pump water heaters were estimated. Specifically, energy-saving effects were estimated based on the estimation results of quantity of heat-pump water heaters to be introduced by using the information about the efficiency based on the sale of boilers and heat-pump water heaters in respective fiscal years. The efficiencies of respective units are set based on various surveys as shown in the table below.

Table 4-5 Efficiencies of heat-pump water heaters and boilers

	2020	2030	2040
Heat-pump water heaters (General areas)	4.81	5.40	6.01
Heat-pump water heaters (Cold Climate areas)	4.54	5.10	5.69
Heat-pump water heaters (1kW)	5.50	6.00	6.50
Boilers	0.78	0.78	0.78

4.3.2 Estimation results of energy-saving effects

The energy-saving effects (reductions from the 2012 level) in the middle-rank case are shown in Table 4-6 by area and capacity.

There are small energy-saving effects in the cross section of 2020 when the proliferation speed that remains slow for a while after commencement of proliferation is reflected and when it is assumed that sufficient proliferation cannot be expected for a while. But, if heat-pump water heaters come into wider use over the long term, large energy-saving effects can be expected. However, the difference between heat-pump water heaters for general areas and those for cold climate areas is obvious, and the energy-saving effects of the units for cold climate areas are expected to be fully demonstrated further later.

However, because of the assumption that the efficiency of heat-pump water heaters continues to go up in and after 2030 in proportion to the increase in stocks, it is considered that energy-saving effects continue to rise from 2030 through 2040.

In 2040, energy-saving effects of 80,000,000 GJ per year can be expected by all units in total.

Table 4-6 Comparison of energy-saving effects by area and capacity (Middle-rank case)

Unit: Thousand GJ/Year

	2020	2030	2040
22kW (General areas)	1,693	26,357	36,189
22kW (Cold climate areas)	0	129	5,233
4.5kW (General areas)	1,323	19,538	26,755
4.5kW (Cold climate areas)	0	88	3,578
1 k W	0	258	10,246
Total	**3,016**	**46,370**	**82,001**

Also, the changes in energy-saving effects by area and capacity in the middle-rank case are shown in Fig. 4-5. It shows reduction effects compared with the 2012 level but it can be found that the effects are not realized in the first five years from FY2013 and the effects become large in around 2020.

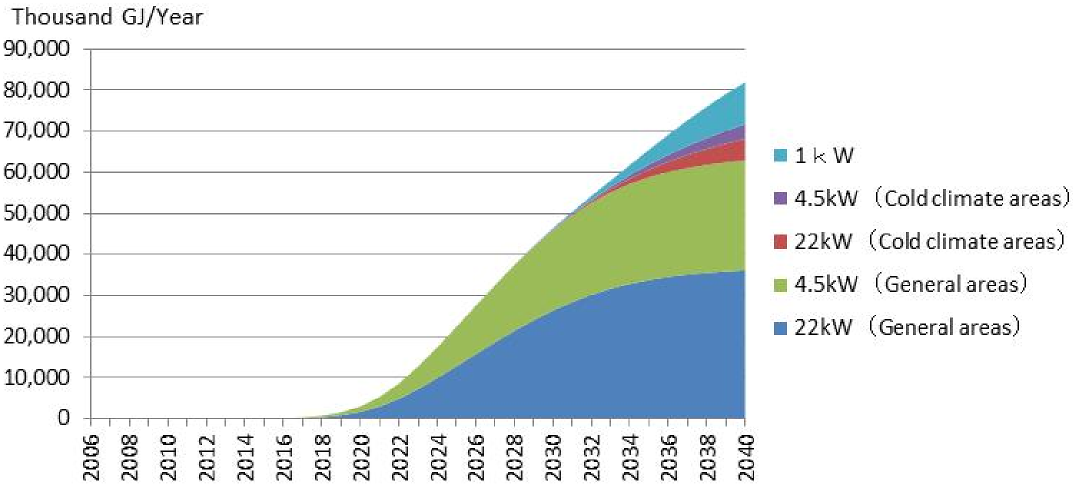


Figure 4-5　Comparison of the amount of energy-saving effects by area and capacity (Middle-rank case)

5. Commercial air conditioners

5.1 Confirmation of markets

As is the case with commercial heat-pump water heaters, the data of total floor areas of buildings in commercial sector are organized.

Then, based on the data of total floor areas, we estimated the installed cooling capacity and cooling and heating demand in commercial sector by using the intensity of installed cooling capacity per total floor area by application and the intensity of annual cooling and heating demand by application. The intensity of installed cooling capacity per total floor area and the intensity of annual cooling and heating demand are set based on various pieces of the existing literature such as "Private Sector Energy Data Survey" by the Institute of Energy Economics, Japan and others.

Moreover, as air-conditioning systems are generally decided by the applications and scales of buildings in many cases, here we assumed the types of typical systems (central systems, building multi split type air conditioners and package air conditioners) that are introduced for respective applications and scales.

Based on the assumption mentioned above, we assumed the installed capacity and cooling demand by type of systems as shown in Fig. 5-1. The total stock capacity of building multi split type air conditioners is 54.9 million kW and that of central systems is 57.2 million kW.

Table 5-1 Installed air conditioning capacity for commercial use

	Total floor areas (Million m²)	Intensity of installed capacity (kW/m²)	Installed capacity (Million kW)	Intensity of cooling demand (GJ/m²)	Intensity of heating demand (GJ/m²)	Total of cooling demand (Million GJ/Year)	Total of heating demand (Million GJ/Year)
Offices	482	—	50.4	—		57.7	25.5
699m² or less	161	0.10	16.8	0.09	0.04	14.45	6.40
700 – 2,999m²	120	0.10	12.6	0.10	0.04	11.58	5.13
3,000 – 9,999m²	81	0.10	8.5	0.15	0.07	12.30	5.45
10,000m² or more	120	0.10	12.5	0.16	0.07	19.36	8.57
Stores	470	—	65.6	—		124.1	34.8
699m² or less	130	0.14	18.1	0.22	0.06	28.46	7.97
700 – 2,999m²	110	0.14	15.3	0.24	0.07	26.27	7.35
3,000 – 9,999m²	71	0.14	9.9	0.20	0.05	13.95	3.91
10,000m² or more	160	0.14	22.3	0.35	0.10	55.46	15.53
Restaurants and bars	66	0.14	9.2	0.23	0.06	14.80	4.14
Schools	363	—	30.0	—		9.0	4.0
Nursery schools	16	0.08	1.3	0.02	0.01	0.30	0.13
Kindergartens	13	0.08	1.1	0.02	0.01	0.26	0.11
Elementary, junior high and high schools	255	0.08	21.0	0.02	0.01	4.88	2.16
Universities	60	0.08	4.9	0.04	0.02	2.66	1.18
Others schools	19	0.08	1.6	0.04	0.02	0.86	0.38
Hotels	92	—	8.1	—		16.4	13.1
699m² or less	25	0.09	2.2	0.05	0.04	1.20	0.96
700 – 2,999m²	26	0.09	2.3	0.19	0.15	4.87	3.89
3,000 – 9,999m²	21	0.09	1.8	0.24	0.19	4.87	3.90
10,000m² or more	21	0.09	1.8	0.26	0.21	5.47	4.37
Hospitals	111	—	11.6	—		18.3	16.9
Clinics	29	0.10	3.1	0.06	0.05	1.75	1.62
Hospitals	81	0.10	8.5	0.20	0.19	16.55	15.31
Others	251	—	28.0	—		62.9	23.3
Welfare facilities	32	0.12	3.7	0.20	0.19	6.50	6.01
Beauty and hair dressing services	15	0.14	2.0	0.14	0.06	2.06	0.91
Sport facilities	13	0.08	1.0	0.08	0.03	0.99	0.44
Golf courses	8	0.10	0.9	0.21	0.06	1.76	0.49
Theaters, amusement places	36	0.12	4.2	0.17	0.08	6.19	2.74
Others than the abo	147	0.11	16.2	0.31	0.09	45.36	12.70

5.2 Central systems

As for central air-conditioning systems for commercial use, we assumed replacement from conventional absorption refrigerators to highly efficient heat-pump heat source equipment and estimated the introduction quantity of and the amount of energy to be saved by heat-pump heat source equipment.

5.2.1 Estimation of introduction quantity of central systems

(1) Assumption of upper limits on introduction quantity of central systems

Of the installed air-conditioning capacities for commercial use, the total of the installed air-conditioning capacities whose applied systems are central systems, i.e., the alternative potential of central systems as stocks, is 57.2 million kW as described above. Whereas, the average service life of heat-pump heat source equipment of central systems is assumed to be 15 years, and the alternative potential of flow of the said equipment is assumed to be 3.81 million kW on annual average.

The above-mentioned alternative potential of heat pumps means the quantity of heat pumps that can be introduced in the case of the largest possible estimation. Whether it is achieved (actualized) in reality or not depends on circumstances.

Here, we set several cases of ratios (actualization rates) to what extent to be actualized among the heat pump alternative potential assumed earlier, and calculated the upper limit on the introduction of heat pumps based on such cases assumed.

Upper limit on introduction of heat pumps
= flow alternative potential of heat pumps x actualization rate

The results of introduction of central systems (total of systems for commercial use and industrial use) in 2013 are as shown in Table 5-2, according to the "Number of Units Delivered in Japan by Product" by JRAIA. Of central systems, the ratio of heat-pump equipment including centrifugal chillers is expressed by "chilling units + centrifugal chillers" / "chilling units + centrifugal chillers + absorption refrigerators" according to the ratio of total capacity. And, the ratio in 2013 is 75%.

Table 5-2 Results of introduction of central systems for commercial use and industrial use (FY 2013)

	Average capacity [kW/Unit]	Introduction quantity [Unit]	Total capacity [kW]	Ratio
Chilling units	203.3	12,401	2,521,123	61%
Centrifugal chillers	2,006.1	295	591,811	14%
Absorption refrigerators	605.4	1,669	1,010,486	25%

Reference;"National shipments of each product" JRAIA

Taking it into consideration that the ratio of heat pumps tends upward, we assumed three cases of ratios (actualization rates) to be occupied by heat pumps in the quantities of central systems to be introduced in the future, i.e., 80%, 90% and 100%. The upper limits on capacity of introduction flows of central systems in respective cases are shown in the table below.

Table 5-3 Table of assumed cases of actualization rates

	Upper limit of flow/ Maximum
Case 80%	3.05 [Million kW] (867 thousand Rt)
Case 90%	3.43 [Million kW] (976 thousand Rt)
Case 100%	3.81 [Million kW] (1084 thousand Rt)

(2) Assumption of proliferation curve of central systems

We assumed that the introduction quantity of central systems on a flow basis increases in proportion to a logistic curve. The initial year of the curve is assumed to be 2004, and we set the shape of the curve by setting the upper limit on the introduction quantity in proportion to the actual values in 2013 and actualization rates. The actual values in 2013 are estimated by excluding the after-mentioned units for industrial use from the total capacity of units for commercial use and industrial use as shown in Table 5-2.

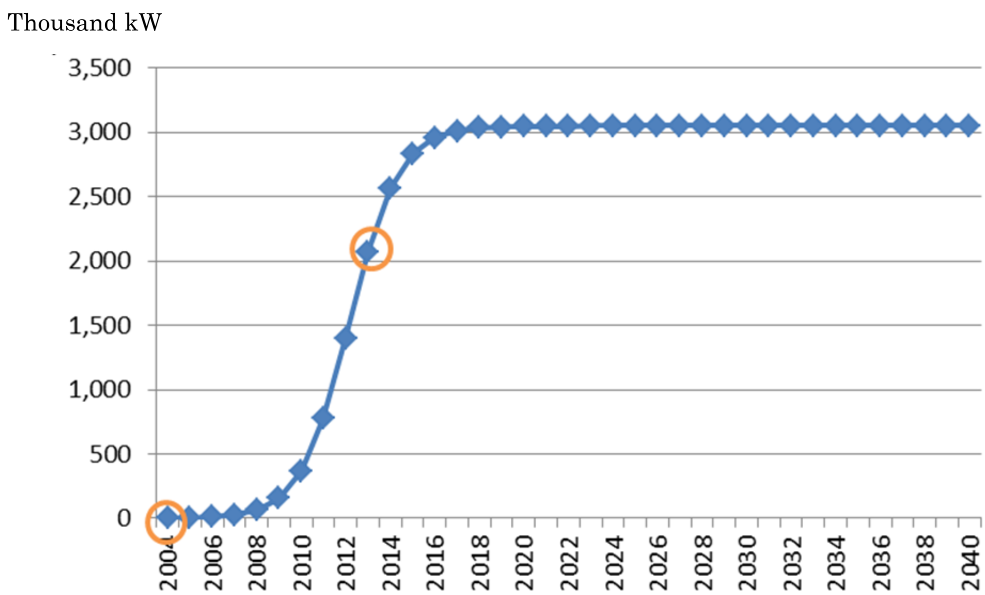


Figure 5-1 Assumption of proliferation curve of central systems (Case 80%)

(3) Assumption of survivor curve of central systems

Based on the calculation results of introduction targets on a flow basis, we assumed the present quantity of stocks upon the assumption of survivor curves. Assuming that the survivor curve has the same shape as that of the "survivor curve of air conditioners" and that the average service life of units is 15 years, we decided parameters to make the survivor rate in the 15th year to be 50%.

(4) Estimation results of introduction quantity of central systems

1) Estimation results of quantity of flow introduction

The introduction quantity on a flow basis in the 80%, 90% and 100% cases are shown in the table below. As of 2013, the introduction quantity reached to about one-third to half of the upper limit on introduction. In all of the cases, though the heights of upper limits are different, the quantity is expected to move closer to the upper limit roughly in and before 2020.

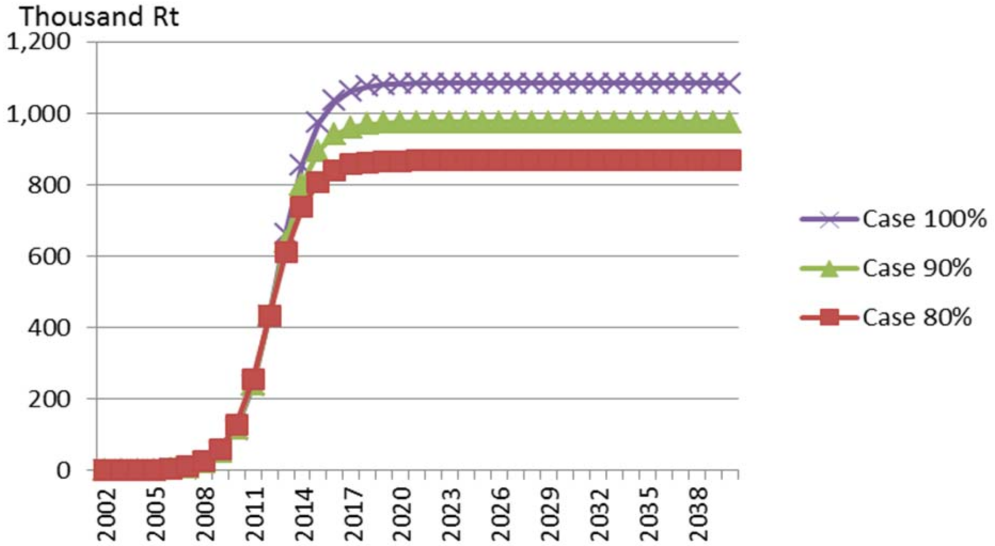


Figure 5-2　Estimation of introduction quantity of central systems (on a flow basis)

2)　Estimation results of quantity of stock introduction

Based on the quantity of flow introduction as calculated above, we estimated the introduction quantity on a stock basis by taking account of the survivor curve upon accumulation of such quantity. The quantities of introduction of central systems in the 80%, 90% and 100% cases are shown as follows on a stock basis.

Though stocks start up later than flows, stocks are expected to rapidly grow in the 2020s when flows reach the upper limit and reach the peak in the 2030s.

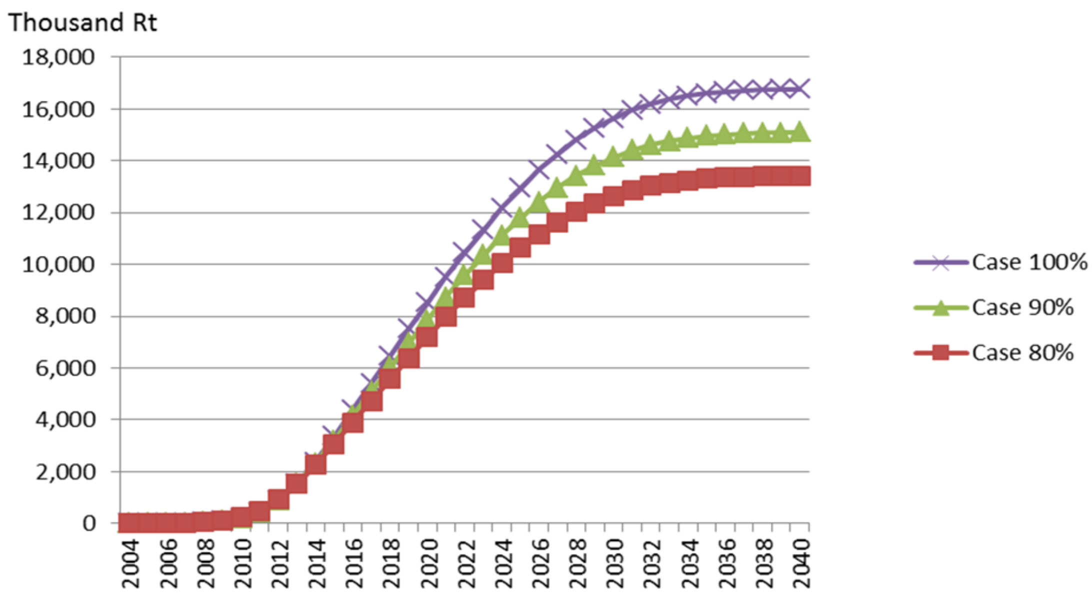


Figure 5-3　Estimation of quantity of stock introduction of central systems (on a stock basis)

5.2.2 Estimation of energy-saving effects of central systems

(1) Preconditions

The energy-saving effects of replacement from conventional absorption refrigerators to highly efficient heat-pump heat source equipment were estimated. Specifically, the energy-saving effects were estimated based on the estimation results of introduction quantity of heat-pump heat source equipment by using the information about the efficiency of heat-pump heat source equipment and absorption refrigerators sold in respective fiscal years. The efficiencies of respective pieces of equipment were set based on various surveys as shown in the table below.

Table 5-4 Efficiencies of absorption refrigerators and highly efficient heat-pump heat source equipment

	2020	2030	2040
Highly efficient heat-pump heat source equipment	6.94	7.70	8.00
Absorption refrigerators	0.90	0.90	0.90

(2) Estimation results of energy-saving effects

The energy-saving effects rise in proportion to stock effects and reach the peak in the 2030s. For reference, the energy-saving effects are calculated on a trial basis as the reduction effects from the 2012 level.

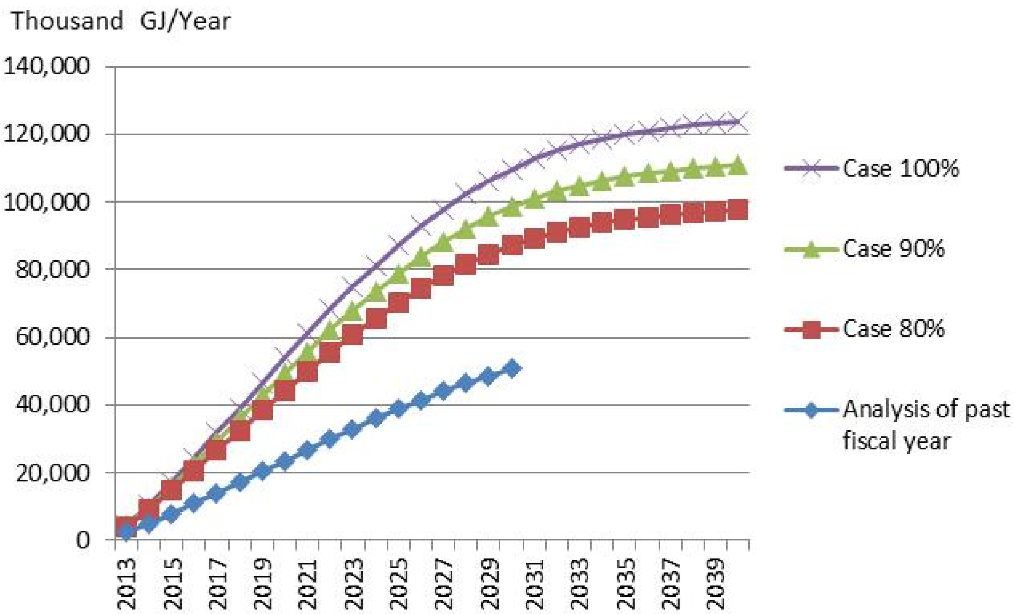


Figure 5-4 Energy-saving effects of central systems

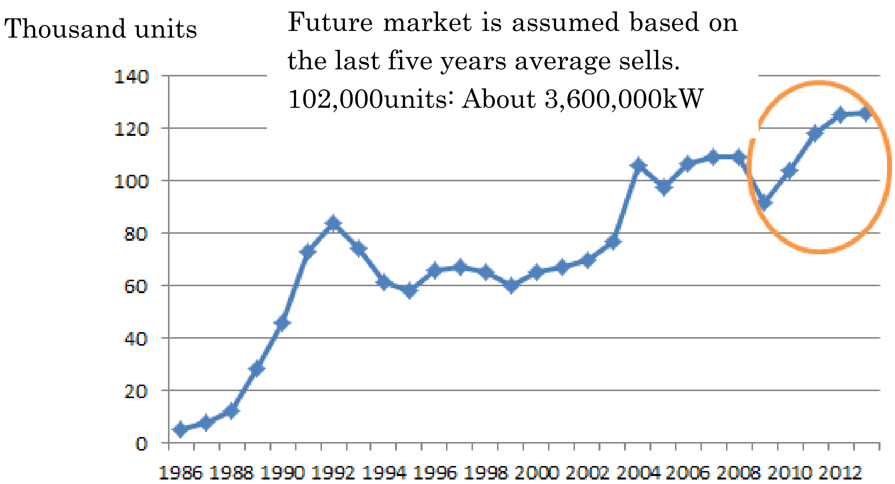
5.3 Building multi split type air conditioners for commercial use

As for building multi split type air conditioners, among air-conditioning units for commercial use, we assumed replacement from conventional multi split type air conditioners to highly efficient building multi split type air conditioners and estimated the introduction quantity of and the amount of energy conservation of highly efficient building multi split type air conditioners.

5.3.1 Estimation of introduction quantity of building multi split type air conditioners for commercial use

(1) Assumption of upper limit on introduction quantity of building multi split type air conditioners for commercial use

Of the number of building multi split type air conditioners delivered in Japan according to voluntary statistics of JRAIA, the average value in the latest five years is assumed as an annual market of building multi split type air conditioners as a whole, whereas the number of building multi split type air conditioners for commercial use delivered and the capacity delivered are roughly estimated to be 102,000 units and 3,600,000 kW, respectively by assuming that the ratio of units for commercial use is about 90% and the capacity of single unit is 35 kW. This level was set as introduction potential of highly efficient building multi split type air conditioners for commercial use.



Source: JRAIA

Figure 5-5 Changes of number of (conventional + highly efficient) building multi split type air conditioners for commercial/industrial use delivered in Japan

The above-mentioned potential is the maximum possible introduction quantity of highly efficient building multi split type air conditioners for commercial use. The actual introduction quantity is assumed by multiplying the actualization rate. Here, it is considered that the ratio of the latest number of highly efficient types introduced remains at about 50%, and three cases are assumed as the actualization rates of potentials of highly efficient types, i.e., 90%, 70% and 50%. In this case, the upper limits on the number of highly efficient types are assumed to be 92,000 units, 71,000 units and 51,000 units, respectively.

(2) Assumption of proliferation curve of building multi split type air conditioners for commercial use

It is assumed that the number of highly efficient building multi split type air conditioners to be delivered increases in proportion to a logistic curve. The shape of logistic curve is set based on the number of highly efficient building multi split type air conditioners for commercial use which have been delivered so far.

In setting an approximated curve, the upper limit numbers of units to be introduced (92,000 units, 71,000 units and 51,000 units) and some other data are required. Here, the year 2001 when highly efficient types were launched is set as the initial fiscal year of proliferation curve. The ratios of highly efficient types to the number of building multi split type air conditioners delivered are assumed to be 35,700 units (41%) in 2005 and 44,100 units (46%) in 2006 according to the past surveys[1]. As the ratio remained at about 50% in the latest five years, the number of units in 2011 is set at 53,000 units (50%). Approximated curves are set as shown in Figs. 5-6, 5-7 and 5-8 based on these points and the upper limits on introduction quantity in proportion to the cases of actualization rates.

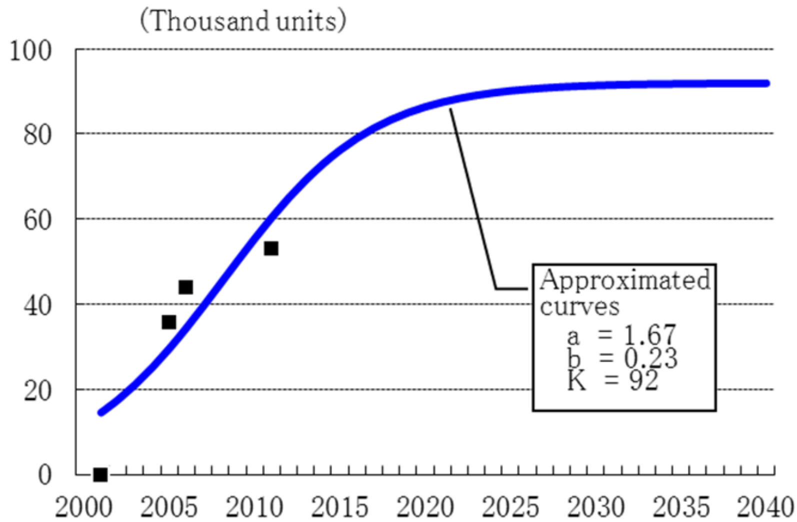


Figure 5-6 Proliferation curve of highly efficient building multi split type air conditioners for commercial use: case 90%

Note 1: HPTCJ survey: Follow-up survey on "systems to subsidize support projects for introduction of highly efficient air conditioners" (2008)

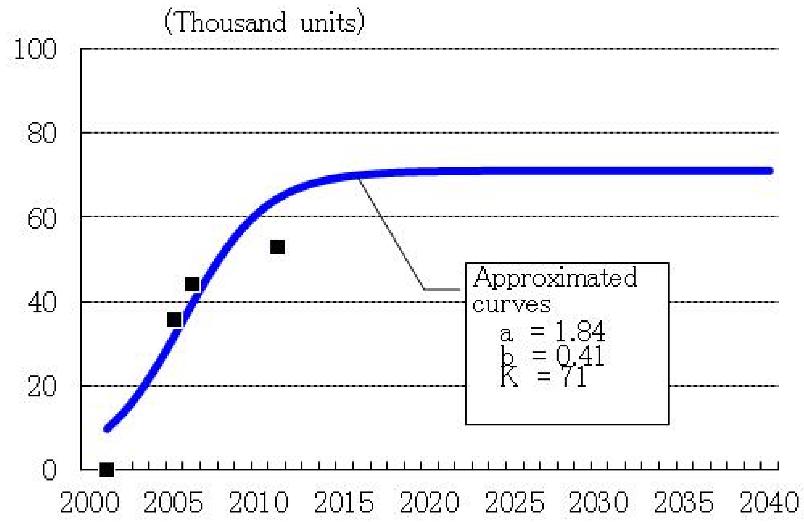


Figure 5-7 Proliferation curve of highly efficient building multi split type air conditioners for commercial use: case 70%

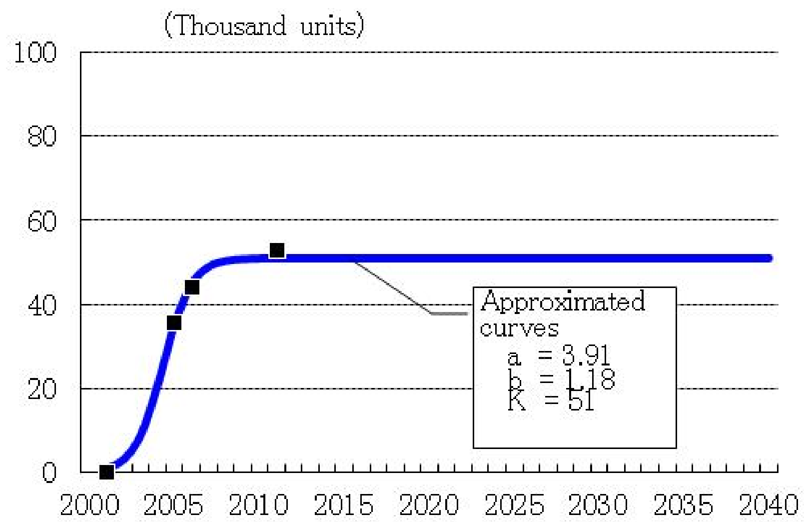


Figure 5-8 Proliferation curve of highly efficient building multi split type air conditioners for commercial use: case 50%

(3) Assumption of survivor curve of building multi split type air conditioners for commercial use

A survivor curve that is similar to that of central systems was assumed.

(4) Estimation results of introduction quantity of building multi split type air conditioners for commercial use

1) Estimation results of quantity of flow introduction

Based on the assumption mentioned above, the quantities of introduction of highly efficient building multi split type air conditioners for commercial use in the respective cases for actualization rates of 90%, 70% and 50% are as follows. The quantities in 2005 and 2006 are based on the actual results and the quantities in and after 2007 are estimated values.

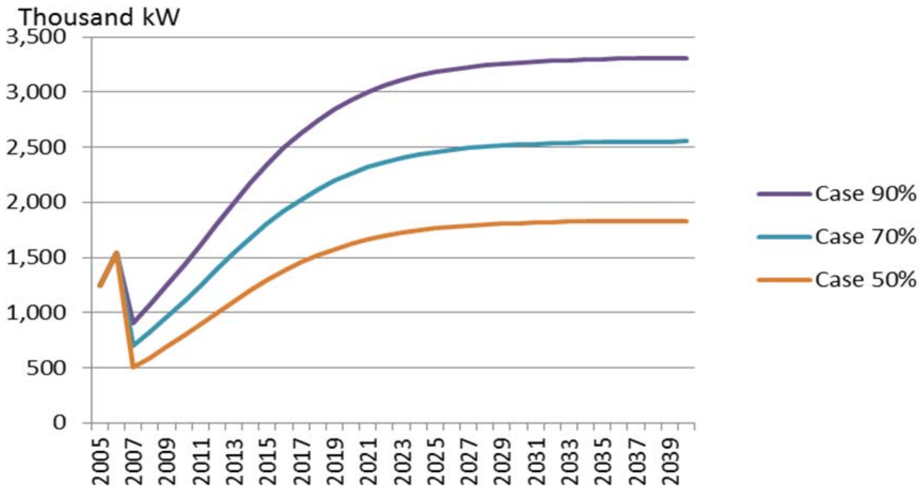


Figure 5-9 Estimation of introduction quantity (flow basis) of highly efficient building multi split type air conditioners for commercial use

2) Estimation results of quantity of stock introduction

Based on the quantity of flow introduction as calculated above, we estimated the quantities of introduction on a stock basis by taking account of the survivor curve upon accumulation of such quantity. The quantities of introduction of highly efficient building multi split type air conditioners for commercial use in respective cases on a stock basis are as follows.

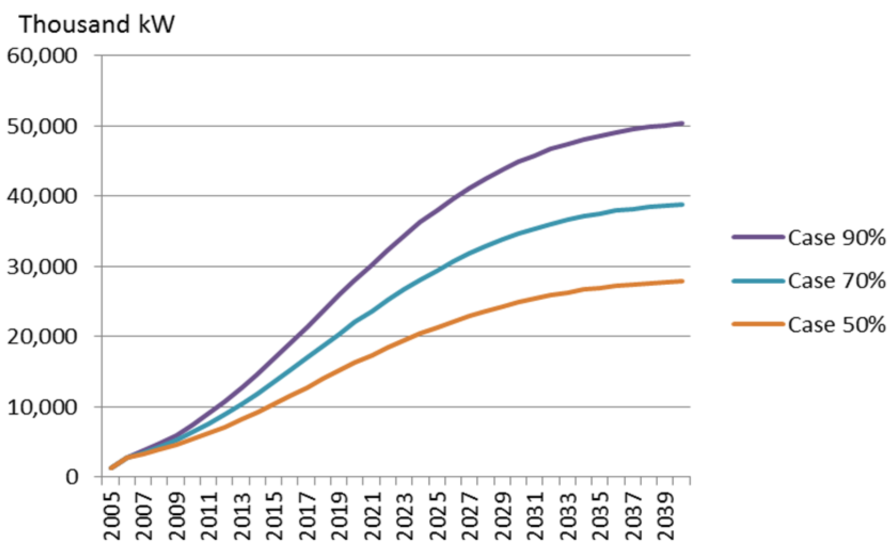


Figure 5-10 Estimation of introduction quantity (stock basis) of highly efficient building multi split type air conditioners for commercial use

5.3.2 Estimation of amount of energy saved by building multi split type air conditioners for commercial use

(1) Preconditions

The energy-saving effects of replacement from conventional building multi split type air conditioners to highly efficient building multi split type air conditioners were estimated. Specifically, the energy-saving effects were estimated based on the estimation results of introduction quantity of highly efficient building multi split type air conditioners by using the information about the efficiency of conventional multi split type air conditioners and highly efficient building multi split type air conditioners sold in respective fiscal years. The efficiencies of respective pieces of equipment were set based on various surveys as shown in Table 5-5.

Table 5-5 Efficiency of building multi split type air conditioners for commercial use

	2020	2030	2040
Highly efficient building multi split type air conditioners	5.20	6.00	6.50
Conventional building multi split type air conditioners	3.00	3.00	3.00

(2) Estimation results of energy-saving effects

The energy-saving effects are expected to increase in and after 2040. While the quantity of stocks stalls in and after the 2030s, the efficiency of highly efficient building multi split type air conditioners continues to increase from 6.00 in 2030 to 6.50 in 2040. This is regarded as a factor of such increase.

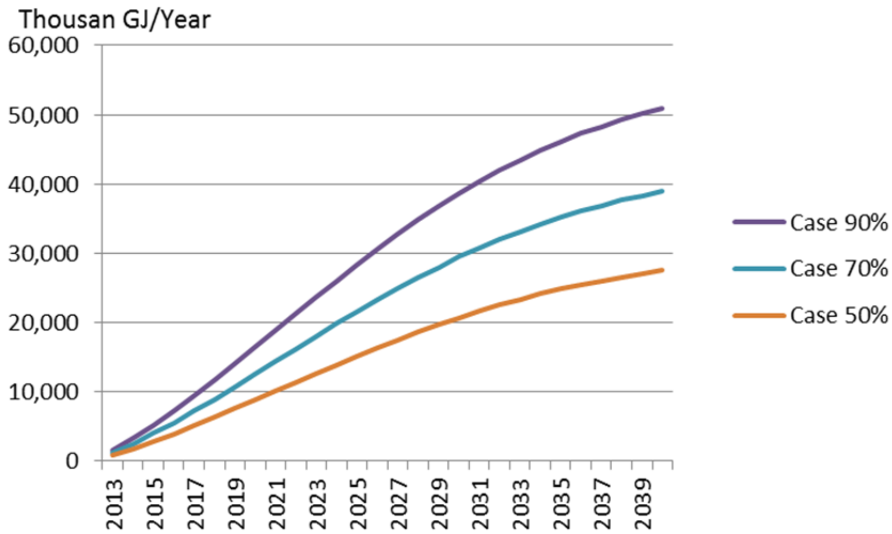


Figure 5-11 Energy saving effects by highly efficient building multi-air conditioners for commercial use

6. Industrial use

In the industrial sectors where a huge amount of energy is consumed in industrial processes, drastic reduction in energy consumption and CO_2 emissions can be expected by introducing heat pumps. Steam of boilers is used for process heat for a wide range of applications such as hot water supply, drying, cleaning, cooking, steaming, heating at low temperature (for fermentation and others) and direct heating (heating of iron pots and others).

Heat pumps can be applied mainly at temperatures lower than 100℃ for applications such as hot water supply, cleaning, drying and heating at low temperature in many cases. Air conditioning is strictly controlled in many types of industry, depending on business types and applications, where it is considered basically possible to apply heat pumps. In recent years, moreover, practical use of heat pumps has become possible at temperatures of 100℃ or higher.

Therefore, as the concept of proliferation goals of heat pumps in industrial sector, among the types of energy used by boiler for industrial use, in addition to application at temperatures lower than 100℃ such as:

- Air conditioning in factories
- Heating (low-temperature heating for fermentation, hot water supply and cleaning)
- Low-temperature drying (lower than 100℃)

We made an outlook for proliferation of heat pumps that produce heat of 100℃ or higher:

- High temperature applications and calculated the energy-saving effects.

In respect of hot water supply and cleaning, as there are many points common to low-temperature heating from the viewpoint of heating water to temperatures of several tens of degrees centigrade, they are considered in a collective manner as "heating."

6.1 Confirmation of markets

6.1.1 Assumption of energy consumption in breakdown by types of boilers for industrial use

It is difficult to grasp the energy consumption in industrial sector by the applications mentioned above. Therefore, it is necessary to make the estimation based on a common framework to a certain extent as a premise, rather than considering the introduction quantity by different methods. Here, we grasped the amount of energy consumed for boilers by types of industry and then assumed the ratios of energy consumed in respective applications of boilers (air conditioning in factories, heating, low-temperature drying and high temperature applications).

The amount of energy consumed by boilers by type of industry is set based on "Energy Consumption Statistics in FY2012 (Estimation Table Including Dynamic Statistics on Consumption of Oil and Others)" of the Ministry of Economy, Trade and Industry.

The composition ratios of consumption in respective applications to the amount of energy consumed by boilers are set based on surveys on typical production processes and others of respective types of industry.

The amount of energy consumed by boilers in breakdown by types of industry, which was estimated by the assumption mentioned above, is shown in the table below. The amount of fuels consumed by boilers in the manufacturing industry as a whole is 1,531 PJ.

Table 6-1 Amount of fuels consumed by boilers by types and the breakdown by respective applications

	Breakdown result of the respective application of boiler fuels					Amount of fuels cosumed by boiler (Thousand GJ)				
	Total	Air conditioning	Heating	Drying below 100℃	High-temperature	Total	Air conditioning	Heating	Drying below 100℃	High-temperature
Manufacture of food	100%	15%	15%	30%	40%	107,481	16,122	16,122	32,244	42,993
Manufacture of beverages, tobacco and feed	100%	30%	30%	20%	20%	29,706	8,912	8,912	5,941	5,941
Manufacture of textile mill products, except apparel and other	100%	20%	60%	—	20%	56,714	11,343	34,028	—	11,343
Manufacture of apparel and other	100%	22%	16%	9%	53%	4,609	1,027	718	412	2,453
Manufacture of lumber and wood products, except furniture	100%	22%	16%	9%	53%	14,533	3,239	2,263	1,298	7,733
Manufacture of furniture and fixtures	100%	22%	16%	9%	53%	615	137	96	55	328
Manufacture of pulp, paper and paper products	100%	10%	10%	25%	55%	397,038	39,704	39,704	99,260	218,371
Publishing, printing and allied industries	100%	22%	16%	9%	53%	3,441	767	536	307	1,831
Manufacture of chemical and allied products	100%	20%	10%	10%	60%	339,545	67,909	33,955	33,955	203,727
Manufacture of petroleum and coal products	100%	10%	10%	—	80%	138,534	13,853	13,853	—	110,827
Manufacture of plastic products	100%	30%	5%	10%	55%	20,238	6,071	1,012	2,024	11,131
Manufacture of rubber products	100%	20%	5%	—	75%	9,289	1,858	464	—	6,967
Manufacture of leather products and fur skins	100%	22%	16%	9%	53%	43	10	7	4	23
Manufacture of ceramic, stone and clay products	100%	10%	5%	5%	80%	60,913	6,091	3,046	3,046	48,731
Manufacture of iron and steel	100%	7%	3%	—	90%	275,820	19,307	8,275	—	248,238
Manufacture of non-ferrous materials and products	100%	10%	5%	—	85%	9,514	951	476	—	8,087
Manufacture of fabricated metal products	100%	22%	16%	9%	53%	8,887	1,980	1,384	793	4,729
Manufacture of general machinery	100%	40%	10%	10%	40%	19,104	7,642	1,910	1,910	7,642
Manufacture of electrical machinery, equipment and supplies	100%	60%	20%	5%	15%	4,832	2,899	966	242	725
Manufacture of transportation equipment	100%	30%	30%	10%	30%	18,098	5,430	5,430	1,810	5,430
Manufacture of precision instruments and machinery	100%	22%	16%	9%	53%	10,812	2,410	1,684	965	5,754
Miscellaneous manufacturing industries	100%	22%	16%	9%	53%	1,202	268	187	107	639
Industrial sector total	100%	14%	11%	12%	62%	1,530,970	217,930	175,026	184,372	953,641

Reference: "Energy consumption census" "Petroleum consumption dynamic statistics" METI

6.1.2 Assumption of potential of amount of fuels consumed by boilers that can be replaced by heat pumps

As applications for air conditioning in factories, heating and low-temperature drying require heat at relatively low temperatures of lower than 100℃, it is assumed that all (100%) of the amount of fuels consumed by the existing boilers can potentially be replaced by heat pumps. As for applications at high temperatures of higher than 100℃, on the other hand, though hot-air heat pumps and steam generation heat pumps for applications at about 120℃ are commercialized and development of heat pumps for applications at higher temperatures is also underway, some types of industry have manufacturing processes where even such heat pumps cannot be used. Here, as it is difficult to use heat pumps in the following four types of industry, i.e., pulp & paper and paper-processed product manufacturing, chemical, oil and coal product manufacturing and iron and steel, the replacement potential in these industries are assumed to be 0%. With regard to other 18 types of industry, it is assumed that all (100%) of the amount of fuels consumed by boilers can potentially be replaced by heat pumps.

Table 6-2 Potential amount of fuels consumed by boilers to be replaced by heat-pumps

	Boiler fuel consumption (Thousand GJ)					
	Total	Air conditioning	Heating	Drying below 100℃	High-temperature	Heat pump replace potential
Manufacture of food	**107,481**	16,122	16,122	2,244	42,993	42,993
Manufacture of beverages, tobacco and feed	**29,706**	8,912	8,912	5,941	5,941	5,941
Manufacture of textile mill products, except apparel and other	**56,714**	11,343	34,028	–	11,343	11,343
Manufacture of apparel and other	**4,609**	1,027	718	412	2,453	2,453
Manufacture of lumber and wood products, except furniture	**14,533**	3,239	2,263	1,298	7,733	7,733
Manufacture of furniture and fixtures	**615**	137	96	55	328	328
Manufacture of pulp, paper and paper products	**397,038**	39,704	39,704	9,260	18,371	
Publishing, printing and allied industries	**3,441**	767	536	307	1,831	1,831
Manufacture of chemical and allied products	**339,545**	67,909	33,955	3,955	03,727	
Manufacture of petroleum and coal products	**138,534**	13,853	13,853	–	10,827	
Manufacture of plastic products	**20,238**	6,071	1,012	2,024	11,131	11,131
Manufacture of rubber products	**9,289**	1,858	464	–	6,967	6,967
Manufacture of leather products and fur skins	**43**	10	7	4	23	23
Manufacture of ceramic, stone and clay products	**60,913**	6,091	3,046	3,046	48,731	48,731
Manufacture of iron and steel	**275,820**	19,307	8,275	–	48,238	
Manufacture of non-ferrous materials and products	**9,514**	951	476	–	8,087	8,087
Manufacture of fabricated metal products	**8,887**	1,980	1,384	793	4,729	4,729
Manufacture of general machinery	**19,104**	7,642	1,910	1,910	7,642	7,642
Manufacture of electrical machinery, equipment and supplies	**4,832**	2,899	966	242	725	725
Manufacture of transportation equipment	**18,098**	5,430	5,430	1,810	5,430	5,430
Manufacture of precision instruments and machinery	**10,812**	2,410	1,684	965	5,754	5,754
Miscellaneous manufacturing industries	**1,202**	268	187	107	639	639
Industrial sector total	**1,530,970**	217,930	175,026	184,372	953,641	162,119

High temperature:
In four types of industry, heat pumps cannot be used and replacement potential is zero.
In other types of industry, heat pumps replacement potential is 100%.

Air conditioning in factories, heating and drying: The amount of fuels consumed by boilers is the potential (100%) of replacement by heat pump on an as-is basis.

6.2 Estimation of introduction quantity of industrial heat pumps

6.2.1 Assumption of upper limits on introduction

(1) Assumption of upper limits on the amount of fuels consumed by boilers to be replaced by heat pumps

The above-mentioned potential of replacement to heat pumps is the maximum possible introduction quantity of industrial heat pumps. The actual introduction quantity is assumed by multiplying the actualization rate. In this survey, actualization rates are set in several cases, and the upper limits on the amount of fuels consumed by boilers to be replaced by heat pumps are calculated based on such cases

Upper limits on the amount of fuels consumed by boilers to be replaced by heat pumps = potential of the amount of fuels consumed by boilers to be replaced by heat pumps x actualization rates

1) Assumption of actualization rates

For heat pumps for air conditioning in factories, heating and low-temperature drying, actualization rates are set for each type of industry on an across-the-board basis. As shown in Table 6-3, three cases of ① through ③ are set for actualization rates of respective applications.

Table 6-3 Actualization rates of air conditioning in factories, heating and low-temperature drying (①-③)

	Air conditioning in factories	Heating	Low-temperature drying
①	80%	70%	70%
②	70%	50%	50%
③	60%	30%	30%

For heat pumps for high-temperature applications, the volumes that can be targeted by heat pumps in respective types of industry were assumed to differ, and actualization rates were set, which differ in proportion to the composition ratios of high-temperature applications to the amount of fuels consumed by boilers by middle classification of industry as mentioned earlier. As shown in the table below, three cases of actualization rates for high-temperature applications were set.

Table 6-4 Actualization rates of high-temperature applications (A-C)

Composition ratios of high-temperature applications to the amount of fuels consumed by boilers by middle classification of industry	Value of actualization rates of high-temperature applications		
	Case A	Case B	Case C
Below 40%	80%	70%	60%
40 to 60 %	70%	60%	50%
Above 60%	60%	50%	40%
Weighted average of all the industries	69%	59%	49%

As shown in the table below, a total of nine different cases were set by the case settings of ① through ③ by application and by the combination of A to C. For reference, ②B is defined as a middle-rank case.

Table 6-5 Table of set cases of actualization rates

Case	Air conditioning	Heating	Drying	High-temperature		
				Composition ratios of fuels for boilers in respective types of industry		
				Less than 40%	Less than 60%	60 % or more
①A	80%	70%	70%	80%	70%	60%
①B	80%	70%	70%	70%	60%	50%
①C	80%	70%	70%	60%	50%	40%
②A	70%	50%	50%	80%	70%	60%
②B	70%	50%	50%	70%	60%	50%
②C	70%	50%	50%	60%	50%	40%
③A	60%	30%	30%	80%	70%	60%
③B	60%	30%	30%	70%	60%	50%
③C	60%	30%	30%	60%	50%	40%

2) Assumption results of upper limits on the amount of fuels consumed by boilers to be replaced by heat pumps

Based on the set values of potentials of the amount of fuels consumed by the above-mentioned boilers to be replaced and those of actualization rates, we estimated the upper limits on the amount of fuels consumed by boilers to be replaced by heat pumps. The estimation results in case ②B are shown in Table 6-6.

Table 6-6 Assumption by industry and applications of upper limits on the amount of fuels consumed by boilers to be replaced by heat pump: Case ②B

	Ratio of high-temperature process among total	Boiler fuel consumption (Thousand GJ)						Heat that could be provided from heat pump (ThousandGJ)				
		Total	Air conditioning	Heating	Drying below 100℃	High-temperature		Total	Air conditioning	Heating	Drying below 100℃	High-temperature
							Heat pump replace potential					
Manufacture of food	40%	**107,481**	16,122	16,122	32,244	42,993	42,993	**65,564**	11,286	8,061	16,122	30,095
Manufacture of beverages, tobacco and feed	20%	**29,706**	8,912	8,912	5,941	5,941	5,941	**17,824**	6,238	4,456	2,971	4,159
Manufacture of textile mill products, except apparel and other	20%	**56,714**	11,343	34,028	–	11,343	11,343	**32,894**	7,940	17,014	–	7,940
Manufacture of apparel and other	53%	**4,609**	1,027	718	412	2,453	2,453	**2,755**	719	359	206	1,472
Manufacture of lumber and wood products, except furniture	53%	**14,533**	3,239	2,263	1,298	7,733	7,733	**8,687**	2,267	1,131	649	4,640
Manufacture of furniture and fixtures	53%	**615**	137	96	55	328	328	**368**	96	48	27	197
Manufacture of pulp, paper and paper products	55%	**397,038**	39,704	39,704	99,260	218,371		**97,274**	27,793	19,852	49,630	
Publishing, printing and allied industries	53%	**3,441**	767	536	307	1,831	1,831	**2,057**	537	268	154	1,099
Manufacture of chemical and allied products	60%	**339,545**	67,909	33,955	33,955	203,727		**81,491**	47,536	16,977	16,977	
Manufacture of petroleum and coal products	80%	**138,534**	13,853	13,853	–	110,827		**16,624**	9,697	6,927	–	
Manufacture of plastic products	55%	**20,238**	6,071	1,012	2,024	11,131	11,131	**12,446**	4,250	506	1,012	6,678
Manufacture of rubber products	75%	**9,289**	1,858	464	–	6,967	6,967	**5,016**	1,300	232	–	3,483
Manufacture of leather products and fur skins	53%	**43**	10	7	4	23	23	**26**	7	3	2	14
Manufacture of ceramic, stone and clay products	80%	**60,913**	6,091	3,046	3,046	48,731	48,731	**31,675**	4,264	1,523	1,523	24,365
Manufacture of iron and steel	90%	**275,820**	19,307	8,275	–	248,238		**17,652**	13,515	4,137	–	
Manufacture of non-ferrous materials and products	85%	**9,514**	951	476	–	8,087	8,087	**4,947**	666	238	–	4,043
Manufacture of fabricated metal products	53%	**8,887**	1,980	1,384	793	4,729	4,729	**5,312**	1,386	692	397	2,837
Manufacture of general machinery	40%	**19,104**	7,642	1,910	1,910	7,642	7,642	**12,609**	5,349	955	955	5,349
Manufacture of electrical machinery, equipment and supplies	15%	**4,832**	2,899	966	242	725	725	**3,141**	2,030	483	121	507
Manufacture of transportation equipment	30%	**18,098**	5,430	5,430	1,810	5,430	5,430	**11,221**	3,801	2,715	905	3,801
Manufacture of precision instruments and machinery	53%	**10,812**	2,410	1,684	965	5,754	5,754	**6,463**	1,687	842	483	3,452
Miscellaneous manufacturing industries	53%	**1,202**	268	187	107	639	639	**718**	187	94	54	384
Industrial sector total	11%	**1,530,970**	217,930	175,026	184,372	953,641	162,119	**436,766**	152,551	87,513	92,186	104,515

(2) Assumption results of upper limits on the number of industrial heat pumps to be introduced

The upper limits on the number of stocks of heat pumps to be introduced are estimated by dividing the amount of energy demand that is calculated by multiplying the upper limits on the amount of fuels consumed by boiler system efficiency by the product of annual operation time (operation time equivalent to the total load) and single unit capacity, i.e., the annual quantity of heat supplied by a heat pump.

Upper limits on the number of stocks to be introduced =
upper limits on the amount of fuels consumed by boilers to be replaced by heat pumps x boiler system efficiency / (annual operation time x single unit capacity)

Upper limits on the number of flows to be introduced = upper limits on stocks to be introduced / average service life of equipment

Here, we estimated the upper limits on the number of heat pumps to be introduced by assuming that the output of one heat pump for applications of air conditioning in factories, hot water supply, drying and high temperature applications are 280 kW, 22 kW, 22 kW and 300 kW, respectively and by setting the efficiency, operation time and average service life of boiler systems based on various surveys. As an example, the estimation results in the cases ①A, ②B and ③C are shown in Table 6-7.

Table 6-7 Assumption results of upper limits on the number of industrial heat pumps to be introduced (Case ①A, ②B, ③C)

		CASE①A				CASE②B				CASE③C			
		Air conditioning	Heating	Drying	High-temperature	Air conditioning	Heating	Drying	High-temperature	Air conditioning	Heating	Drying	High-temperature
Amount of fuels consumed by boilers	(thousand GJ/year)	174,344	122,518	129,061	121,763	152,551	87,513	92,186	104,515	130,758	52,508	55,312	87,267
Amount of energy demand	(thousand GJ/year)	156,910	110,267	116,154	87,669	137,296	78,762	82,967	75,251	117,682	47,257	49,780	62,833
Output per HP	(kW/unit)	280	22	22	300	280	22	22	300	280	22	22	300
Operation per HP	(h/year·unit)	1,100	1,700	1,700	1,700	1,100	1,700	1,700	1,700	1,100	1,700	1,700	1,700
Supply heat per HP	(GJ/year)	1,109	135	135	1,836	1,109	135	135	1,836	1,109	135	135	1,836
Upper limits on the number of stocks to be introduced	(thousand unit)	142	819	863	48	124	585	616	41	106	351	370	34
	(thousand kW)	39,624	18,017	18,979	14,325	34,671	12,870	13,557	12,296	29,718	7,722	8,134	10,267
Assumed service life of equipment	(year)	15	10	10	10	15	10	10	10	15	10	10	10
Upper limits on the number of flows to be introduce	(thousand unit)	9	82	86	5	8	58	62	4	7	35	37	3

6.2.2 Assumption of proliferation curve of industrial heat pumps

The introduction quantity of industrial heat pumps on a flow basis was assumed to increase in proportion to a logistic curve.

Here, we made settings with making reference to the proliferation progress of delivery of high-efficiency centrifugal chillers that have appeared in recent years and that are considered having closer relations with heat pumps. Though the amount of high-efficiency units delivered is not clear, we assumed that the increase in centrifugal chillers in and after 1998 represents high-efficiency units, and assumed the speeds (parameters a and b) of approximated curves based the data until 2007 as the peak year of shipping volume.

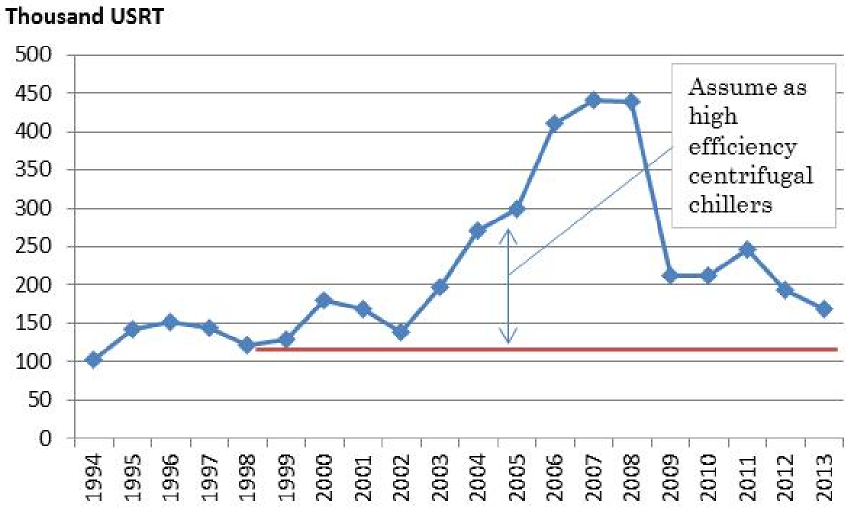


Figure 6-1 Assumption of the capacity delivered of centrifugal chillers and the amount which corresponds to high-efficiency units

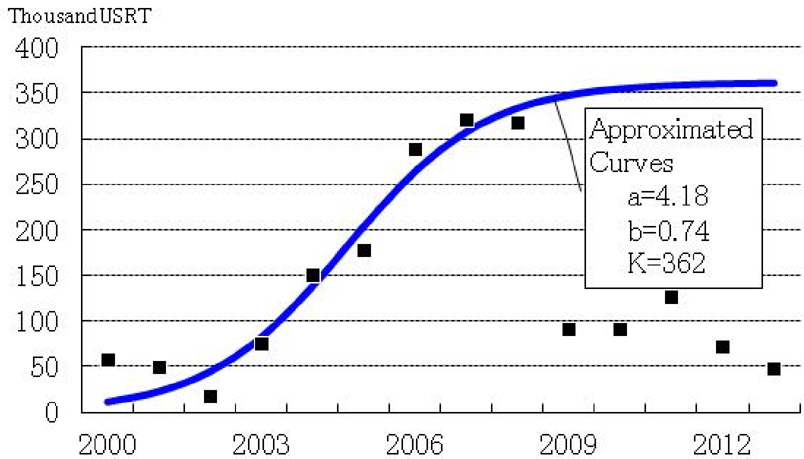


Figure 6-22 Actual number delivered of high-efficiency centrifugal chillers (estimation) and approximated curve

According to the assumption of the applicable approximated curves, it can be said that the introduction comes close to the upper limit in a little less than 10 years and the assumption represents curves of proliferation in a relative high speed.

As for proliferation starting year, since in all cases industrial heat pumps for heating and low-temperature drying began in 2007, that for high temperature applications in 2011, in consideration of the fact that heat-pump equipment has been introduced earlier for air conditioning in factories, it was set to FY2005.

6.2.3 Assumption of survivor curve of industrial heat pumps

Based on the calculation results of introduction quantity on a flow basis, we estimated the amount of stocks upon the assumption of survivor curves.

Assuming that the survivor curve has the same shape as that of the "survivor curve of air conditioners" and that the average service life of heat pumps for air conditioning in factories is about 15 years and that of heat pumps for heating, drying and high temperature applications is about 10 years, we decided parameters to make the survivor rate in the 15th year and the 10th year of service life to be 50%.

6.2.4 Estimation results of introduction quantity of industrial heat pump

(1) Estimation results of quantity of flow introduction

The changes in the capacity of heat pumps to be introduced (flow basis) in the total of all applications (air conditioning in factories, heating, drying and high temperature applications) for industrial use are shown in Fig. 6-3. Here, among the cases assumed, the three cases of high-rank (①A), middle-rank (②B) and low-rank (③C) are compared with each other.

In all of the cases, the introduction flow is assumed to fully start up in 2020. In and after 2020, the flow is expected to remain almost unchanged, and the proliferation of industrial heat pumps is expected to be relatively rapid.

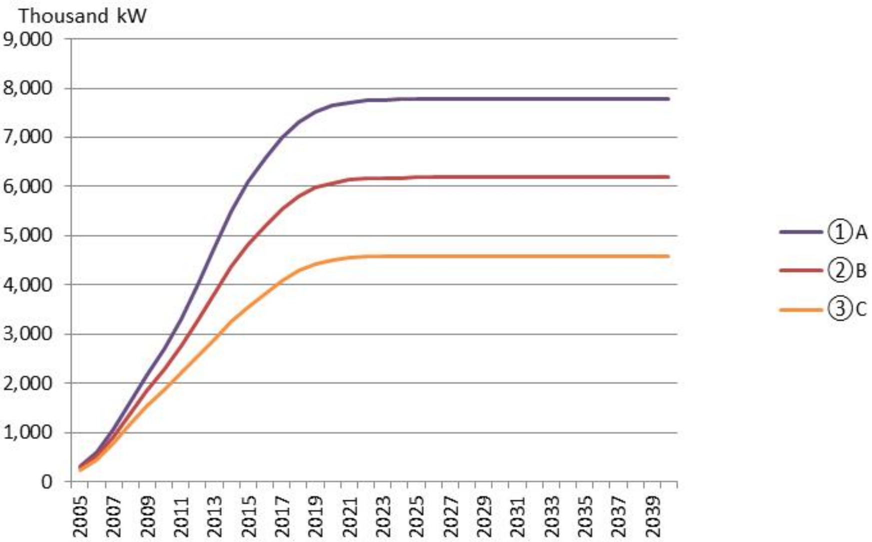


Figure 6-3 Comparison of introduction flow (Total of industrial use)

Then, the introduction quantity (flow basis) by application is shown in Table 6-8. It can be found that all of the applications nearly reach their upper limits in 2020.

Table 6-81　Comparison of introduction flow (by industrial applications)

Units: Thousand kW

Applications	Case	2020	2030	2040
For air-conditioning	①	2,641	2,642	2,642
	②	2,311	2,311	2,311
	③	1,981	1,981	1,981
For heating	①	1,794	1,802	1,802
	②	1,281	1,287	1,287
	③	769	772	772
For drying	①	1,890	1,898	1,898
	②	1,350	1,356	1,356
	③	810	813	813
For high temperature	A	1,321	1,432	1,433
	B	1,134	1,230	1,230
	C	947	1,027	1,027

(2)　Estimation results of quantity of stock introduction

The changes in the capacity of heat pumps to be introduced (flow basis) in the total of all applications (air conditioning in factories, heating, drying and high temperature applications) for industrial use are shown in Fig. 6-4.

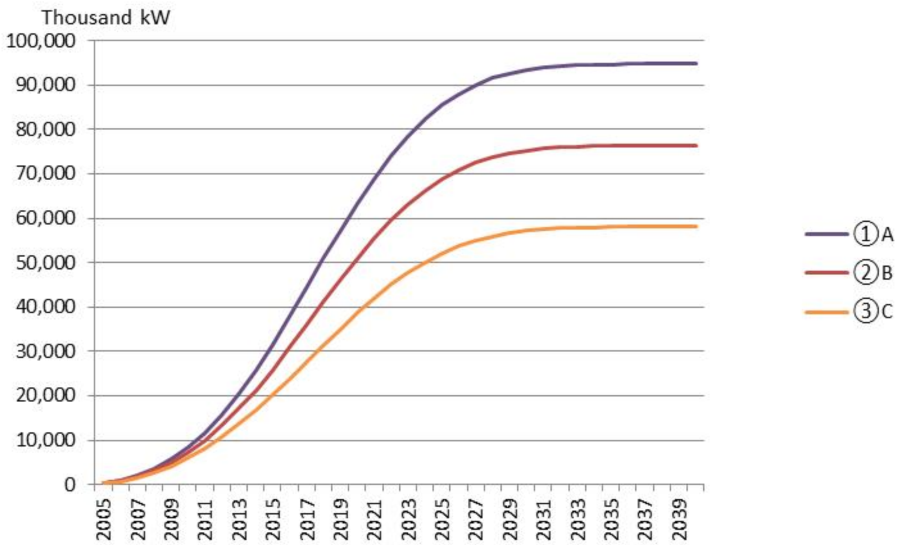


Figure 6-4　Comparison of introduction stock (Total of industrial use)

Then, the introduction quantity (flow basis) by application is shown in Table 6-9. All of the applications reflect the rapid proliferation in an early stage and the introduction quantity in 2020 is very large. However, as flows remain stable at a high level in stocks, it can be found that the quantity continues to increase in and after 2020 and becomes stable in the 2030s.

Table 6-9 Comparison of introduction stock (by industrial applications)

Units: Thousand: kW

Applications	Case	2020	2030	2040
Air-conditioning	①	30,985	40,372	40,906
	②	27,112	35,325	35,792
	③	23,239	30,279	30,679
Heating	①	13,048	18,805	18,901
	②	9,320	13,432	13,501
	③	5,592	8,059	8,101
Drying	①	13,745	19,808	19,911
	②	9,818	14,149	14,222
	③	5,891	8,490	8,533
High temperature	A	5,499	14,386	15,027
	B	4,720	12,348	12,898
	C	3,941	10,310	10,770

6.3 Estimation of energy-saving effects of industrial heat pumps

6.3.1 Preconditions

The energy-saving effects of replacement from boilers to highly efficient heat-pump equipment for industrial use were estimated. Specifically, the energy-saving effects were estimated based on the estimation results of introduction quantity of industrial heat pumps by using the information about the efficiency of boilers and industrial heat pumps sold in respective fiscal years. The efficiencies of respective pieces of equipment were set based on various surveys as shown in the table below.

Table 6-10 Efficiencies of industrial heat pumps and boilers

	2020	2030	2040
Heat pumps for air conditioning	5.20	6.00	6.50
Heat pumps for heating	3.50	4.00	4.50
Heat pumps for drying	4.25	5.00	5.50
Heat pumps for high temperature	3.50	4.00	4.25
Boilers	0.90	0.90	0.90

6.3.2 Estimation results of energy-saving effects

The total energy saving effects (comparison with the year 2012) of heat pumps for industrial use in all applications are shown in Fig. 6-5.

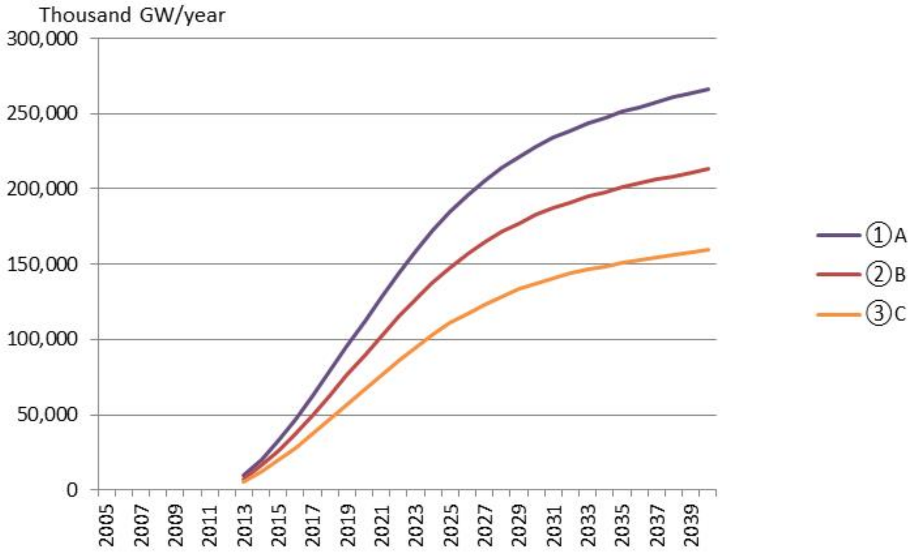


Figure6-5　Comparison of amount of energy saved (Total of industrial use)

Next, the energy-saving effects by application are shown in Table 6-11.　The growth speed of energy-saving effects is roughly the same as that of stocks. However, the energy-saving effects are expected to become higher in the 2030s, reflecting that the efficiencies in respective applications also improve in and after 2030.

Table 6-10　Comparison of energy-saving effects [Thousand GJ/Year] (by industrial applications)

Applications	Case	2020	2030	2040
Air-conditioning	①	41,092	71,610	82,241
	②	35,956	62,660	71,961
	③	30,819	53,708	61,680
Heating	①	20,358	40,769	51,044
	②	14,541	29,121	36,460
	③	8,724	17,472	21,876
Drying	①	31,784	58,582	67,591
	②	22,703	41,845	48,280
	③	13,621	25,107	28,968
High temperature	A	19,028	57,134	65,619
	B	16,333	49,042	56,324
	C	13,637	40,948	47,031

7. Agricultural use

7.1 Concept of outlook for proliferation of agricultural heat pumps

As for the concept of outlook for proliferation of agricultural heat pumps, basically as is the case with industrial heat pumps, the three cases of high rank, middle rank and low rank were set by the actualization rates of upper limits on the number of flows upon calculation of proliferation upper limits on the number of flows. And, the introduction quantity on a stock basis was calculated by setting survivor curves upon calculation of the introduction quantity on a flow basis by logistic curves as is the case with other heat pumps.

7.2 Preconditions of outlook for proliferation of agricultural heat pumps

7.2.1 Setting of upper limits on introduction of agricultural heat pumps

In setting the upper limits on the number of agricultural heat pumps to be introduced, we calculated the amount of energy demand by multiplying the areas covered by combustion-type equipment in agricultural facilities by annual usage of fuel oil per unit area and boiler efficiency, and then we estimated the upper limits on introduction of agricultural heat pumps by setting the single unit capacity and annual operation time of agricultural heat-pump equipment. A list of data required for calculation of the upper limits on introduction is shown in the table below.

	Used data	Calculation method	Calculated value
(1)	Usage of fuel oil per unit area	Based on precondition below	564.4[L/a]
(2)	Areas covered by combustion-type equipment in agricultural facilities	Status of Glass Rooms and Greenhouses Installed for Horticulture," Published by Japan Greenhouse Horticulture Association in 2009	185,140[a]
(3)	Total heat(= amount of fuels consumed by boilers)	(1)×(2)×39.1[MJ/L]	4,343[Thousand GJ/Year]
(4)	Energy demand	(3)×0.9 (: Boiler efficiency)	3,909[Thousand GJ/Year]
(5)	Output per heat pump unit	Based on heating capacities of existing facilities	23.0[kW]
(6)	Operating hours per heat pump unit	Based on operation results of existing facilities Source from Chiba University	1,200[h]
(7)	Heat supplied per heat pump unit	(5)×(6)×3.6／1,000	99[GJ/Year]

(8)	Upper limits on the amount of stocks	(4)／(7)	39[Thousand units] 905[Thousand kW]
(9)	Assumption of average lifetime		10[Year]
(10)	Upper limits on the amount of flows	(8)／(10)	3.9[Thousand units]

In setting the usage of fuel oil (fuel oil A is assumed) per unit area of (1) in the table, among the typical items of vegetables, fruit trees and flowers, the usage of fuel oil used for those items that are grown in glass rooms and greenhouses (with using heating equipment) is calculated, and the method to calculate weighted averages in proportion to planted areas is used.

Table 7-1 Calculation of usage of fuel oil per unit area: Vegetables

	Green onion	Cucumber	Eggplant	Big tomato	Mini tomato	Green pepper	Sweet Green Pepper	Strawberry	Melon	Watermelon
Total planting area per household	3,803	2,185	2,870	3,501	2,717	3,599	918	2,465	5,773	7,056
Cost of heat, light and power per 10a (Yen)	36,000	248,000	367,000	278,000	360,000	498,000	691,000	281,000	147,000	37,000
Cost of fuel oil A per 10a (Yen)	33,865	233,294	345,237	261,515	338,652	468,469	650,024	264,337	138,283	34,806
Usage of fuel oil A per 10a (L)	462	3,180	4,706	3,565	4,616	6,386	8,861	3,603	1,885	474

In the table mentioned above, vegetables are cited as examples and the calculation method of usage of fuel oil per unit area is stated. As for the "cost of heat, light and power per 10 a," the data of the cost of heat, light and power, which are cited from the "Agricultural Management Statistical Survey Item-specific Management Statistics in Fiscal 2007" by the Ministry of Agriculture, Forestry and Fisheries, are used. Moreover, it is assumed that the cost of fuel oil A accounts for 94% of the cost of heat, light and power because the installation areas where oil is used account for 94% of the installation areas of heating equipment. Then, the "usage of fuel oil A per 10 a" is estimated by dividing the cost by the fuel oil unit price of 73 yen/l[2] during the same period.

In the case where the average prices of fuel oil used for vegetables as a whole are estimated from item-by-item estimation, it is appropriate to weight-average them in proportion to item-by-item planting scales. Here, they are weight-averaged by the "total planting area per household," which is made public by this survey. As a result, the usage of fuel oil A per 10a of vegetables as a whole is calculated to be 2,908 l.
With the same method, the usage of fuel oil A per 10 a of fruits and that of flowers are calculated to be 215 l and 7,884 l respectively.

Table 7-2 Results of assumption of the usage of fuel oil per unit area

	Vegetables	Fruits	Flowers	weight-average
Fuel oil [L/10a]	2,908	215	7,884	5,644
installation areas of heating equipment [Thousand m^2]	7,551	509	10,454	—

For the average prices of fuel oil used for agriculture as a whole, the weight-average proportional to the installation areas of heating equipment is adopted. Here, weight average is applied in accordance with "Status of Glass Rooms and Greenhouses Installed for Horticulture," which was published by Japan Greenhouse Horticulture Association in 2009. As a result, the usage of fuel oil A per 10 a is roughly calculated to be about 5,644 l.

7.2.2 Setting of actualization rates for upper limits on introduction of agricultural heat pumps

The following three cases are assumed by the methods similar to those used for industrial heat pumps as to the actualization rates for upper limits on introduction (flow).

High-rank case: 70%
Middle-rank case: 50%
Low-rank case: 30%

7.2.3 Setting of proliferation curve of agricultural heat pumps

As for the proliferation curve of agricultural heat pumps, the same logistic curve as that of industrial heat pumps is assumed.

7.2.4 Setting of equipment efficiency

The efficiencies of agricultural heat pumps and boilers are set as shown in Table 7-3.

Table 7-3 Assumption of the efficiencies of agricultural heat pumps

	Year 2010	Year 2020	Year 2030	Year 2040
Agricultural heat pumps	4.0	5.0	6.0	6.5
Boilers	0.9	0.9	0.9	0.9

Note 2: Statistical prices in agriculture sector (announced by the Ministry of Agriculture,

Forestry and Fisheries in 2006 and 2007)

7.3 Estimation of and introduction quantity of agricultural heat pumps and energy-saving effects

Based on the premises mentioned above, the calculation results of the introduction quantity (flow and stock) and energy-saving effects in comparison with the year 2012 are organized as follows.

Table 7-4 Results of estimation of introduction quantity and of the amount of energy savings

			Year 2020	Year 2030	Year 2040
Installed number (flow)	Capacity[Thousand kW]	High-rank	58.4	63.3	63.3
		Middle-rank	41.7	45.2	45.2
		Low-rank	25.0	27.1	27.1
	Number[Thousand units]	High-rank	2.5	2.8	2.8
		Middle-rank	1.8	2.0	2.0
		Low-rank	1.1	1.2	1.2
Installed number (stock)	Capacity[Thousand kW]	High-rank	243.2	636.2	664.5
		Middle-rank	173.7	454.4	474.6
		Low-rank	104.3	272.8	284.7
	Number[Thousand units]	High-rank	10.6	27.7	28.9
		Middle-rank	7.6	19.8	20.6
		Low-rank	4.5	11.9	12.4
Energy saving effect	[Thousand GJ/year]	High-rank	554.8	1,666.2	1,906.8
		Middle-rank	396.4	1,190.1	1,362.0
		Low-rank	238.1	714.6	817.2

8. Conclusion as to outlook for energy-saving effects through proliferation of heat pumps

Based on the analytical results mentioned above, the energy-saving effects through proliferation of heat pumps in the sector of household, commercial, industry and agriculture are organized. In the case where there are several cases, a middle-rank case is always adopted.

Under the estimation of this fiscal year's survey, the energy-saving effects (compared with the year 2012) of 282,754[thousand GJ per year] (2020), 697,289[thousand GJ per year] (2030) and 901,670[thousand GJ per year] (2040) will be realized.
The breakdown of energy-saving effects by field is as shown in the table below.

Table 8-1 Conclusion as to outlook for energy-saving effects through proliferation of heat pumps [Thousand GJ/Year]

			Year 2020	**Year 2030**	**Year 2040**
Residential use			**127,937**	**338,936**	**455,393**
	Water heaters		57,230	145,194	188,300
	Air conditioners		70,707	193,742	267,093
Commercial use			**64,889**	**174,495**	**231,891**
	Water heaters		3,016	46,370	82,001
	Highly efficient air conditioning		61,873	128,125	149,890
		Central systems	49,296	98,660	110,901
		Building multi split type air conditioners	12,577	29,465	38,989
Industrial use			**89,532**	**182,668**	**213,024**
	Air conditioning in factories		35,956	62,660	71,961
	Heating		14,541	29,121	36,460
	Low temperature, drying		22,703	41,845	48,280
	High temperature		16,333	49,042	56,324
Agricultural use			**396**	**1,190**	**1,362**
Total			**282,754**	**697,289**	**901,670**