FY2020 Survey on Heat Pump Diffusion Prospects

Report

August 2020

Heat Pump & Thermal Storage Technology Center of Japan

Introduction

The “Basic Energy Plan” that presents the basic direction of Japan’s energy policy is investigated for the content at a frequency of at least once every 3 years and is modified as required. The current “Fifth Basic Energy Plan” (decided at the July 2018 Cabinet meeting) further reinforces the activities for definite fulfillment of the “Long-term Prospect of Supply and Demand of Energy” (decided by Ministry of Economy, Trade and Industry in July 2015) formulated as the target that the FY2030 energy supply demand structure should achieve, sets forth efforts of energy conversion and decarbonization with the aim of reducing greenhouse gas by 80% till FY2050, and announces the determination of pursuing all possible options. The “Japan's long term strategy under the Paris Agreement ”(decided at the June 2019 Cabinet meeting) formulated as a long-term low greenhouse gas development strategy in response to the Paris Agreement indicates the direction of efforts and measures for achieving a decarbonized society as the ultimate goal and for enabling 80% reduction.

High energy saving capabilities can be mentioned as the biggest feature of heat pumps, but in addition to the capabilities, heat pumps can be utilized for regulating demand, which will be needed to diffuse renewable energy. Heat pumps are the technology to support low-carbon electric power systems utilizing natural energy. Heat pumps are assumed to play an even more important role to promote thoroughgoing energy saving and convert the energy supply demand structure into the long-term decarbonized energy supply and demand structure.

In the present survey, we analyzed final energy consumption reduction effect and an increase or decrease of power consumption, including primary energy consumption reduction effect and greenhouse gas emission reduction effect as quantitative analyses related to heat-pump diffusion effect till FY2050 in Japan.

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1. Prerequisites for the Analysis

In this paper, quantitative analyses related to diffusion of heat pumps in Japan till FY2050 were conducted. At the same time, reduction effects of primary energy consumption and CO2 emissions were analyzed when substitutable heat demand was replaced by heat pumps.

1.1 Targets of the analysis

Table 1-1 shows heat pumps targeted for analysis and detailed analyses in each application.

Table 1-1 Analyzed equipment expected to have heat pumps incorporated and analysis details

Applications		HP equipment	Analysis details
Residential	Hot water supply	Residential HP water heaters	● Effects of substitution of residential HP water heaters for combustion water heaters and electric water heaters ● Efficiency improving effects of residential HP water heaters
	Air-conditioning (Cooling and heating)	Residential air-conditioners	● Effects of substitution of residential air-conditioners for gas heaters and oil heaters in heating applications ● Efficiency improving effects of residential air-conditioners in heating and cooling applications
Commercial	Hot water supply	Commercial HP water heaters	● Effects of substitution of commercial HP water heaters for combustion water heaters ● Efficiency improving effects of commercial HP water heaters
	Air-conditioning (Cooling and heating)	Chilling units Turbo refrigerators	● Effects of substitution of chilling units and turbo refrigerators for absorption chillers ● Efficiency improving effects of chilling units and turbo refrigerators.
		Unitary type air-conditioners	● Efficiency improving effects of unitary type air-conditioners
Industrial	Air-conditioning (Cooling and heating)	Chilling units Turbo refrigerators	● Effects of substitution of chilling units and turbo refrigerators for absorption chillers ● Efficiency improving effects of chilling units and turbo refrigerators
		Unitary type air-conditioners	● Efficiency improving effects of unitary type air-conditioners
	Air-conditioning (Heating) Warming	Industrial HP	● Effects of substitution of industrial HP for industrial boilers ● Efficiency improving effects of industrial HP
Agricultural	Greenhouse heating	Agricultural HP	● Effects of substitution of agricultural HP for agricultural boilers ● Efficiency improving effects of agricultural HP
Others	Snow melting	HP for snow melting	● Effects of substitution of HP for snow melting for electric heating and hot-water heating ● Efficiency improving effects of HP for snow melting

1.2 Primary energy conversion factor, crude oil conversion factor, and CO2 emission factor used for the analysis

(1) Primary energy conversion factor and crude oil conversion factor of electric power

Table 1-2 shows primary energy conversion factor and crude oil conversion factor of electric power used for calculating energy-saving effects.

Table 1-2 Primary energy conversion factor and crude oil conversion factor of electric power

Factor	Target energy type	Factor value	Source
Primary energy conversion factor of electric power	Electric power	9.76 GJ/MWh	Paragraph 3 of Article 4 of Ordinance for enforcement of the Act on the Rational Use of Energy
Crude oil conversion factor	All energy types	0.0258 kL/GJ	

(2) CO2 emission factor of each energy type

Table 1-3 shows CO2 emission factor of each energy type used for calculating CO2 reduction effect.

Table 1-3 List of CO2 emission factors

	CO2 emission factor value	Source
Electric power	FY2018: 0.463 t-CO2/MWh FY2030: 0.370 t-CO2/MWh FY2050: 0.120 t-CO2/MWh	・ FY2018: Actual value at the Electric Power Council for a Low Carbon Society (ELCS) ・ FY2030: FY2030 target value in "Action Plan for a Low carbon Society of ELCS ・ FL2050: FY2050 estimated value in "Strategic Technology Roadmap in Energy Field - Energy Technology Vision 2100" of the Institute of Applied Energy
City gas	0.0498 t-CO2/GJ	・ Calculated by multiplying 44/12 by the emission factor (tC/GJ) in the "List of Calculation Methods and Emission Factors in the system for calculating, reporting, and publishing greenhouse gas emissions" of Ministry of Environment
LPG	0.0591 t-CO2/GJ	
Kerosene	0.0678 t-CO2/GJ	
Fuel oil	0.0693 t-CO2/GJ	

2. Diffusion prospects by sectors

2.1 Residential hot water supply

2.1.1 Prerequisites

(1) Water heaters targeted for evaluation

For residential hot water supply, the evaluation was made on the effects of replacing combustion and electric water heaters with heat pump water heaters. Table 2-1 shows the domestic water heaters which were subject to the evaluation.

The heat pump water heater was defined as a "residential heat pump water heater" whose actual shipment track record is indicated in the self-statistics of JRAIA. The gas and oil-fired water heaters were defined as those whose shipment track record is shown in the self-statistics of JGKA and in the "Heater Almanac" of JHIA.

With respect to counter type storage gas water heaters, storage type closed vessel gas water heaters, and oil burning water heaters for residential use, it was assumed that residential hot water supply accounts for 92.5% and commercial hot water supply accounts for remaining 7.5% in the light of reports of the "METI's 2015 Projects for Promoting a Rational Use of Energy" (survey on energy-saving technologies in industrial furnaces, etc.).

Table 2-1 Residential water heaters targeted for evaluation

Water heaters on analysis	Water heaters on the statistics	
	Statistics name	Targeted water heaters
HP water heaters	Self-statistics of the Japan Refrigeration and Air Conditioning Industry Association (JRAIA)	Residential heat pump water heaters
Gas water heaters	Self-statistics of Japan Industrial Association of Gas and Kerosene Appliances (JGKA)	End stop system instantaneous gas water heaters for residential use
		Bathtub gas water heaters
		92.5% of counter type storage gas water heaters
		92.5% of storage type closed vessel gas water heaters
		Gas-fired water heaters and space heaters used both for hot water supply and space heating
	Heater Almanac of Japan Heating Industrial Association (JHIA)	Gas-fired hot-water boilers for individual residences
Oil-fired water heaters	Self-statistics of Japan Industrial Association of Gas and Kerosene Appliances (JGKA)	92.5% of oil burning water heaters for residential use
		Oil bath boilers
		Oil bath boilers with oil-fired water heaters
	Heater Almanac of Japan Heating Industrial Association (JHIA)	Oil burning boilers of 34.9 kW or less
Electric water heaters	Yearbook of machinery statistics	Electric water heater

(2) Setting of market segments

Since the market of residential heat pump water heaters varies according to residential properties, the home water heater market was divided into four segments of (1) through (4) as shown in Table 2-2. The regional classification was defined as follows:

- Cold region: Hokkaido, Tohoku District (Aomori Prefecture, Iwate Prefecture, Miyagi Prefecture, Akita Prefecture, Yamagata Prefecture, and Fukushima Prefecture), and Hokuriku District (Niigata Prefecture, Toyama Prefecture, Ishikawa Prefecture, and Fukui Prefecture)
- Warm region: Areas other than those mentioned above.

Table 2-2 Segment settings for residential hot-water supply market

Category	Region	Type of houses
(1)	Cold region	Detached houses
(2)	Cold region	Apartment houses
(3)	Warm region	Detached houses
(4)	Warm region	Apartment houses

2.1.2 Calculation flow

Fig. 2-1 shows the calculation flow of heat pump water heater diffusion prospects in the home water heater market.

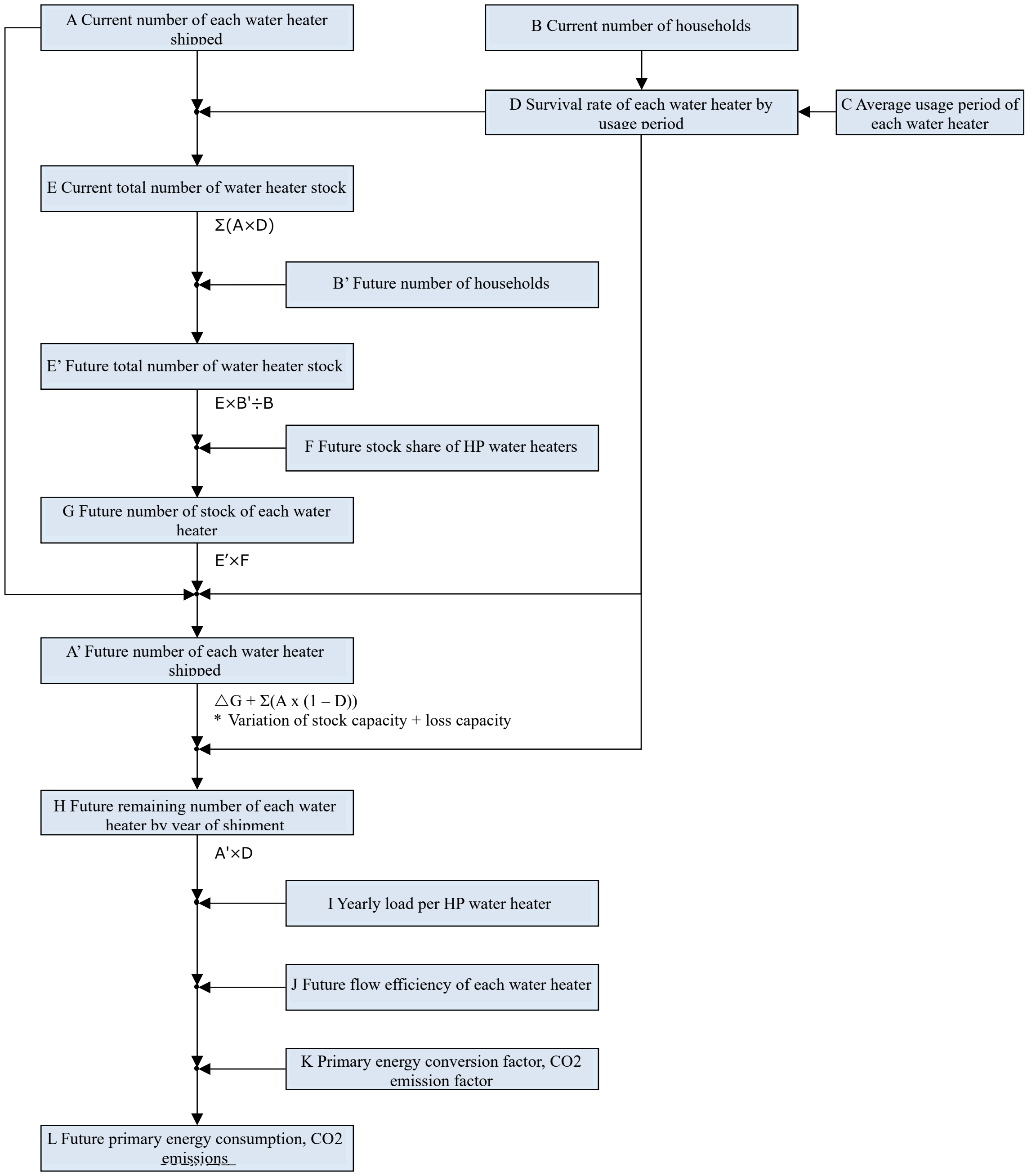


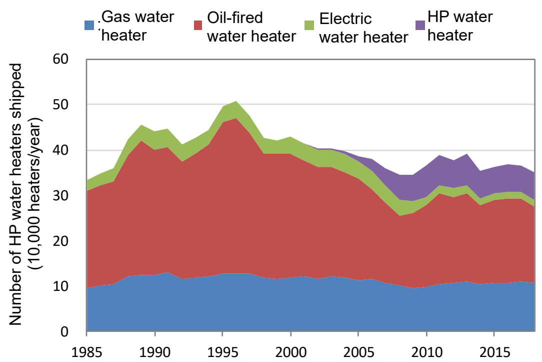
Fig. 2-1 Calculation flow of residential heat pump water heaters

2.1.3 Data used for calculation

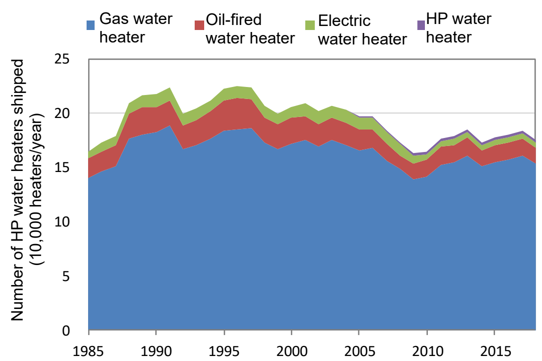
(1) Market size of home hot water supply

1) The number of residential water heaters shipped

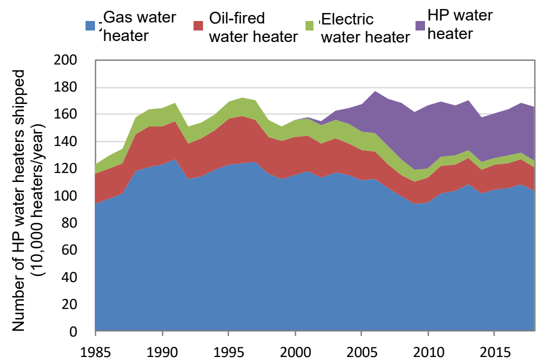
Fig. 2-2 shows changes in the number of respective residence water heaters domestically shipped. When the number of residential water heaters shipped by water heater is viewed, the ratio of oil-burned water heaters is high in detached houses of the cold region, whereas gas water heaters account for a large percentage in apartment houses of the cold region and in the warm region. In and after the 2000s, the ratio of heat-pump water heaters has increased centering around detached houses of the warm region.



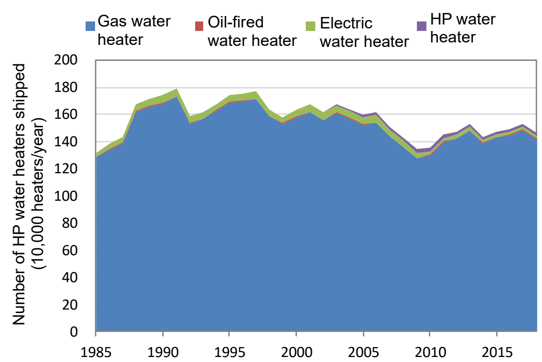
Market segment (1): Cold region and detached houses



Market segment (2): Cold region and apartment houses



Market segment (3): Warm region and detached houses



Market segment (4): Warm region and apartment houses

Fig. 2-2 Changes in the number of residential water heaters shipped

Source) Self-statistics of the Japan Refrigeration and Air Conditioning Industry Association (JRAIA), "Actual sales results and forecast of gas and kerosene appliances" (Japan Industrial Association of Gas and Kerosene Appliances (JGKA), "Actual Status of Gas-fired Water Heaters and Oil-burning Water Heaters" (Gas and Oil-fired Water Heaters Judgment Criteria Working Group), "Heater Almanac" (Japan Heating Industrial Association (JHIA.)), Yearbook of machinery statistics (METI), and others.

The number of heat pump water heaters by cold region and warm region was set by self-statistics of the Japan Refrigeration and Air Conditioning Industry Association (JRAIA). The number of heat-pump water heaters shipped across Japan was set by the self-statistics of JGKA and JHIA, and the data of Gas and Oil-fired Water Heaters Judgment Criteria Working Group. The equipment category whose information is unable to be obtained at the past time point was estimated by applying the rate of change with time, etc. of the number of equipment sold of the relevant category obtained from METI's " Yearbook of machinery statistics."

The breakdown of heat pump water heaters by detached house and apartment house, and that of gas water heaters and oil-fired water heaters by cold region and warm region, as well as by detached house and apartment house were estimated by assuming that they were equal to the breakdown of the number of water heaters used by market segment of each water heater obtained from "Survey and National Test Survey related to Estimation of CO2 emissions from household," (MOE).

2) Average usage period and survival curve of residential water heaters

First of all, the average usage period of residential heat-pump water heaters was set to about 12 years, which is the average usage period of residential heat-pump water heaters in " Survey of studies concerning energy-saving measures of equipment and instruments" (FY2015) (interview with (JRAIA)). For gas water heaters and oil-fired water heaters, too, about 11 years and about 10 years were adopted, respectively, which are average usage periods of gas water heaters and oil-burned water heaters in the Survey (questionnaire as of 2006 conducted by JGKA. About 14 years were set for the average usage period of electric water heaters.

Then, the average usage period was corrected by multiplying uniformly the average usage period of each heater by the correction factor so that the number of stock of residential water heaters obtained by accumulating yearly remaining water heaters, which is estimated by multiplying the aforementioned number of water heaters shipped for each year by the survival rate, is consistent with the number of households described later.

Table 2-3 Assumed average age of service of residential water heaters

Heater types	Average age of service	
	Before correction	After correction
Residential heat pump water heater	12 years	14.9 years
Gas water heater	11 years	13.6 years
Oil-fired water heater	10 years	12.3 years
Electric water heater	14 years	17.3 years

The survival curve (survival rate by usage periods) is given by the following formula. Parameters α and β that express the shape of the survival curve must be set. In the present case, settings were performed in such a manner that the average usage period of commercial water heaters assumed from the survival curve conformed to the assumption of the above-mentioned average usage period.

$$\text{Survival rate} = e^{-\alpha(elapsed\ years^{\beta})}$$

Fig. 2-3 shows the survival curve set as described above.

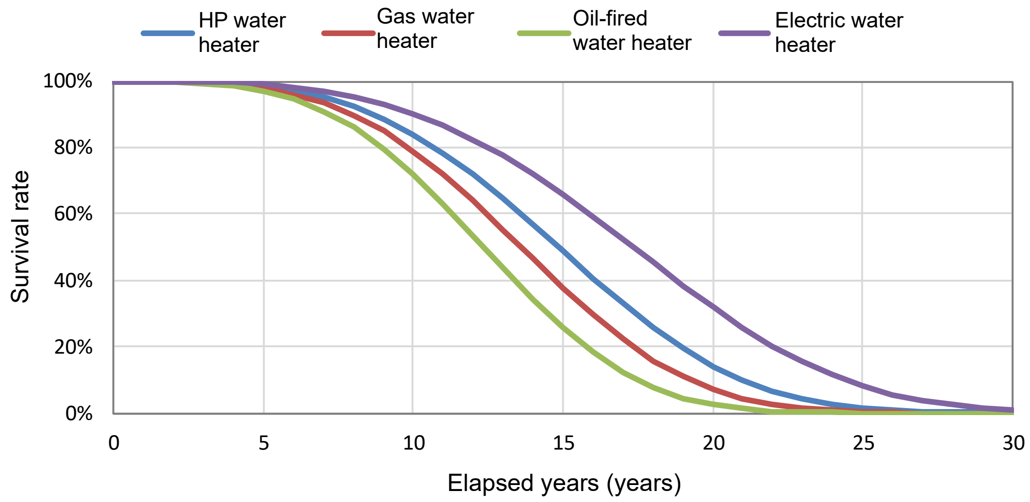


Fig. 2-3 Survival curve of residential water heaters

3) Market size of residential hot water supply market (number of stock)

The yearly remaining number of residential water heaters was estimated by multiplying the foregoing number of residential water heaters shipped for each year by the survival rate and the accumulated results were regarded as the current number of stock of residential water heaters.

In estimating the future number of stock of residential water heaters, the total number of water heaters was set to be proportional to the number of households. The future number of households was estimated as the number of private households by cold region and warm region in accordance with the future estimate of the number of households and population by National Institute of Population and Social Security Research, and the breakdown by detached house and apartment house was estimated using "Housing and Land Survey" (Ministry of Internal Affairs and Communications). Specifically, first, the number of private households by cold region and warm region till FY2040 was estimated on the basis of "Projection of the number of households for Japan (prefectural projection)" (estimated in April 2019). Then, the number of private households in and after FY2040 was estimated on the basis of future population of "Regional Population Projections for Japan" (in March 2018), with the number of people per household presumed to be constant. Next, the breakdown by detached house and apartment house for every cold region and warm region given by "Housing and Land Survey" was presumed to be constant in and after FY2019, and the future number of private households by cold region and warm region as well as by detached house and apartment house was estimated as per Fig. 2-4.

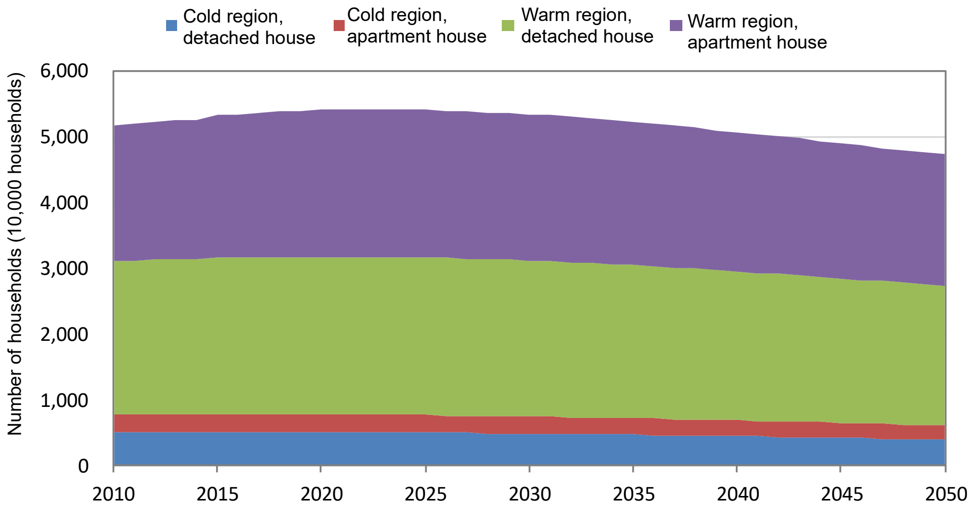


Fig. 2-4 Changes in the number of private households

Source) "Projection of the number of households for Japan (prefectural projection) compiled in April 2019" (National Institute of Population and Social Security Research); " Regional Population Projections for Japan in March 2018" (National Institute of Population and Social Security Research); " Housing and Land Survey" (Ministry of Internal Affairs and Communications), etc.

Fig. 2-5 shows the result of estimating the future market scale (number of stock of residential water heaters) of residential hot water supply by market segment on the basis of the above-mentioned assumption.

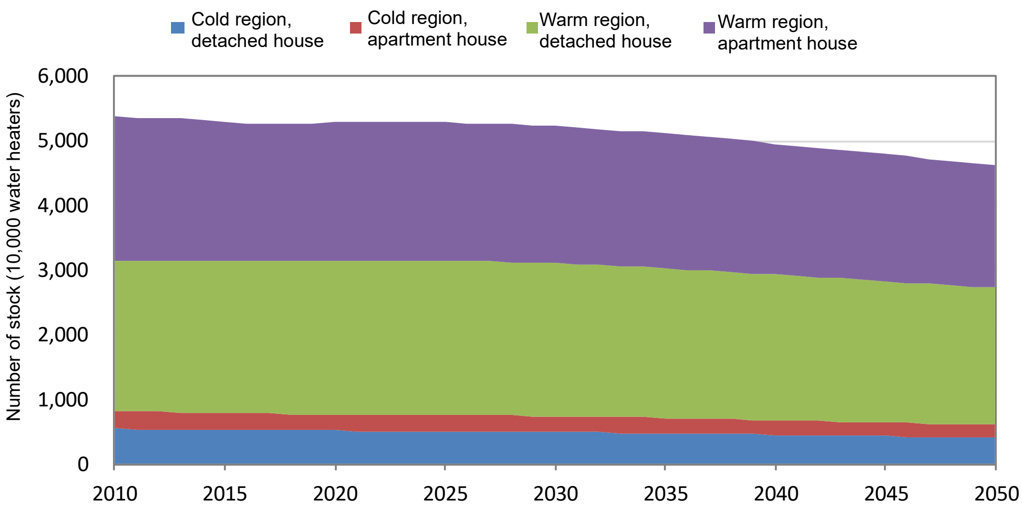


Fig. 2-5 Changes in the future number of stock of residential water heaters by market segment

(2) Stock share of residential heat-pump water heaters

On the basis of the foregoing assumption of actual quantity shipped and survival curve of residential water heaters, the number of stock of each water heater was calculated by accumulating the number of water heaters shipped with the survival rate taken into account, and the current stock share of residential heat-pump water heaters in the residential hot water supply market was estimated as per Fig. 2-6.

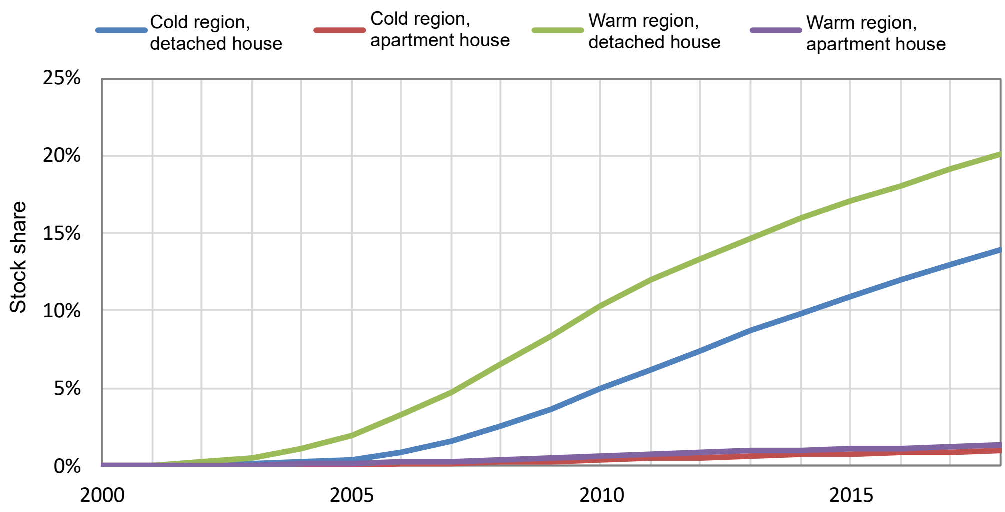


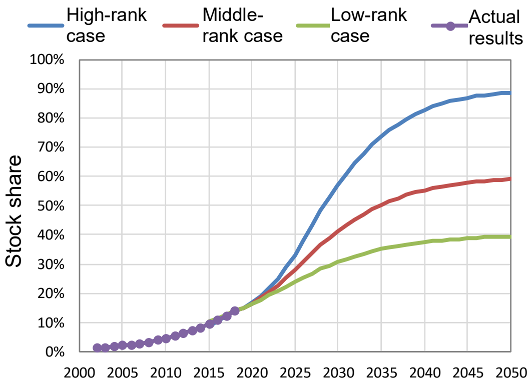
Fig. 2-6 Changes in current stock share of residential HP water heaters

The future actualization rate of residential heat pump water heaters was estimated by applying the logistic curve to the current stock share changing conditions. To apply the logistic regression, as shown in Table 2-4, three cases of high-rank, middle-rank, and low-rank were assumed as upper-limit asymptotic values of shares of residential heat pump water heaters. With respect to the detached house, the shares of residential heat pump water heaters were assumed to approach the upper-limit asymptotic values in about FY2050 when products go through just about 3 product life cycles, whereas with respect to the apartment house, the shares of residential heat pump water heaters were assumed to approach the upper-limit asymptotic values in about FY2065 when products go through just about 4 product life cycles, because it is assumed to be difficult to replace existing equipment.

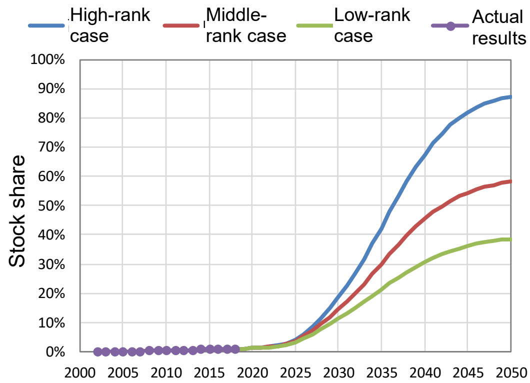
Table 2-4 Assumption of upper introduction limit of residential HP water heaters

Case	Upper introduction limit of residential HP water heaters (upper limit of stock share)
High-rank	Stock capacity of each market segment x 90%
Middle-rank	Stock capacity of each market segment x 60%
Low-rank	Stock capacity of each market segment x 40%

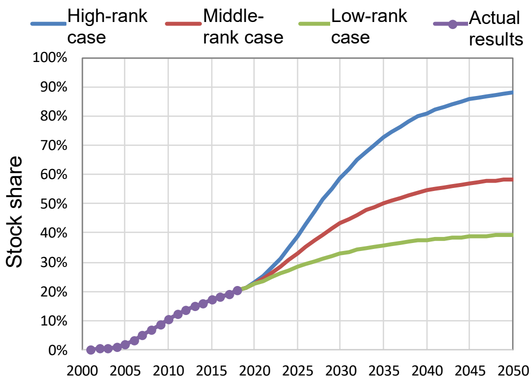
Fig. 2-7 shows the future stock share of residential heat pump water heaters in the residential hot-water supply market, which was estimated on the basis of the foregoing assumption.



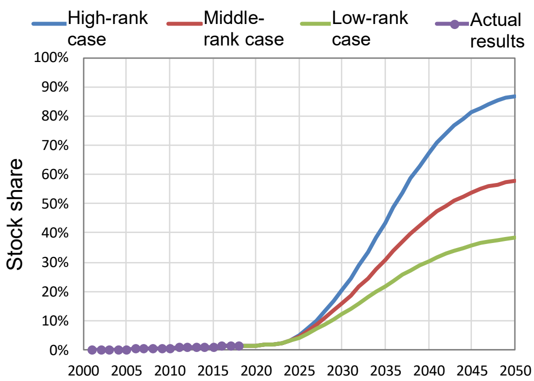
Market segment (1): Cold region, detached house



Market segment (2): Cold region, apartment house



Market segment (3): Warm region, detached house



Market segment (4): Warm region, apartment house

Fig. 2-7 Assumption of future stock share of HP water heaters in the residential hot water supplying market

(3) Flow efficiency of residential water heaters

The flow efficiency of residential water heaters by water heater was set as shown in Fig. 2-8.

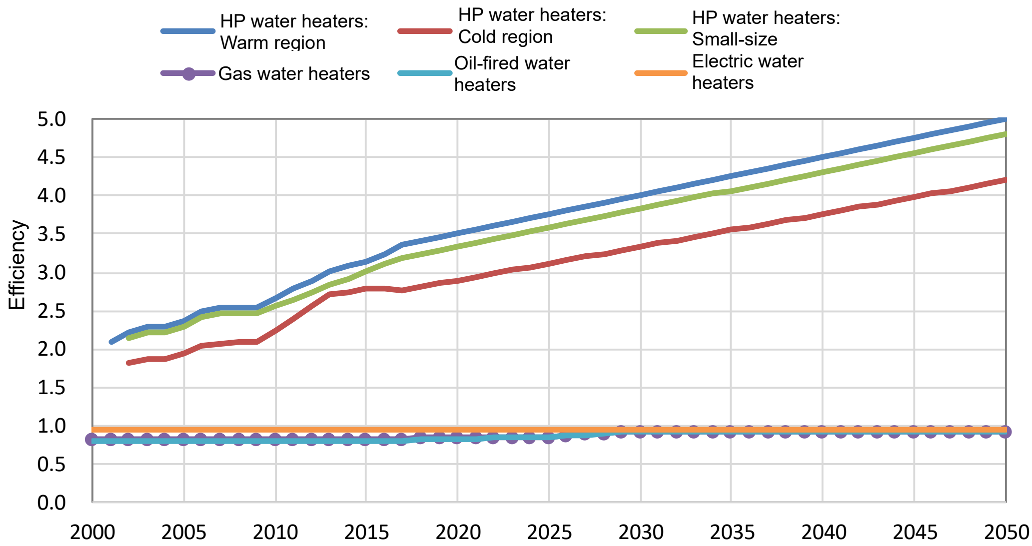


Fig. 2-8 Assumption of flow efficiency of residential water heaters by water heater

With respect to residential heat pump water heaters, the efficiency was set for detached houses in the warm region, detached houses in the cold region, and apartment houses in the cold region, respectively. Residential heat pump water heaters are typically categorized by the Top Runner Program, namely, Category "320 to 550 L, general region, with heat insulation, and one boiler," Category "320 to 550 L, cold region, with heat insulation, and one boiler," and Category "240 to 320 L, general region, with no heat insulation," respectively. Furthermore, the residential heat pump water heaters adopt the FY2009 actual values shown in "Final Decision of Heat Pump Water Heater Judgment Criteria Subcommittee (September 2012)" as well as the actual values in FY2017 and others by category presented in the "First Air Conditioner and Electric Hot Water Heater Judgment Criteria Working Group (June 2019)" as current actual values. It was presumed that the efficiency improvement would take place to about 1.5 times the current status from FY2017 to FY2050. The past data in which the efficiency data based on the measurement methods of JIS C 9220:2011 "Residential Heat Pump Water Heaters" did not exist was set by assuming that the long-term change rate of efficiency value based on JIS C 9220:2011 was 1/2 the long-term change rate of Coefficient of Performance (COP).

With respect to gas-fired water heaters and oil-fired water heaters, on the basis of the actual values shown in the "Draft Final Decision of Heat Pump Water Heater Judgment Criteria Subcommittee," the efficiency was assumed to improve in order to achieve the next top runner program in FY2025, and the ratio of the latent heat recovery type would further reach 100% by FY2030 in the scope of water heaters subject to the present survey.

With respect to electric water heaters, the efficiency was set to be unchanged from the current efficiency studied by Heat Pump and Thermal Storage Technology Center of Japan (HPTCJ).

(4) Yearly load per water heater

The hot water supply load was assumed to be 17.5 GJ/year for the general region and 21.0 GJ/year for the cold region on the basis of hot water keep warm mode calorie of JIS C 9220:2018 for all water heaters (calculated with Tokyo designated as the general region and Morioka as the cold region).

2.1.4 Calculation results

(1) Number of residential heat pump water heaters shipped and number of stock

Fig. 2-9 and Fig. 2-10 show estimation results of the number of residential HP water heaters shipped and the number of stock of residential HP water heaters based on the foregoing assumption.

The number of residential HP water heaters shipped is anticipated to gently increase till around FY2040 after rapidly increasing till around FY2030, particularly, in the high-rank and middle-rank cases. This is assumed that the number of residential HP water heaters shipped would drop as the relevant market becomes saturated after residential HP water heaters with the high economical superiority to other water heaters are introduced by customers at an accelerating pace. In and after around FY2040, renewal demand of residential HP water heaters once introduced would be set off against the effect of decrease of the number of households and the number of residential HP water heaters shipped would decrease generally in a gentle way.

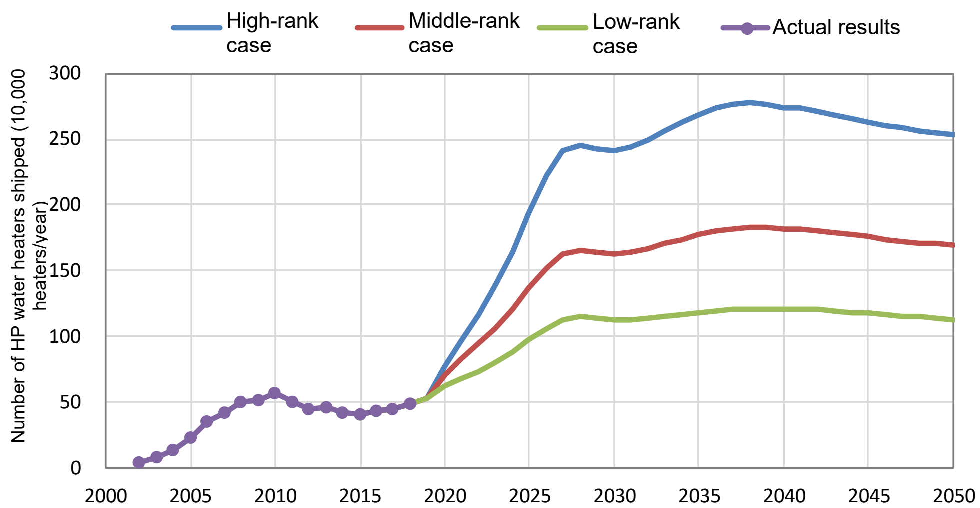


Fig. 2-9 Estimated results of the number of residential HP water heaters shipped

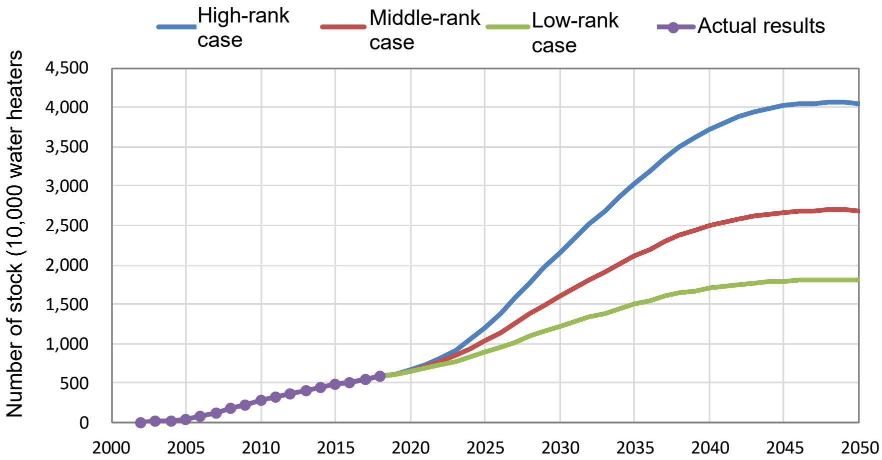
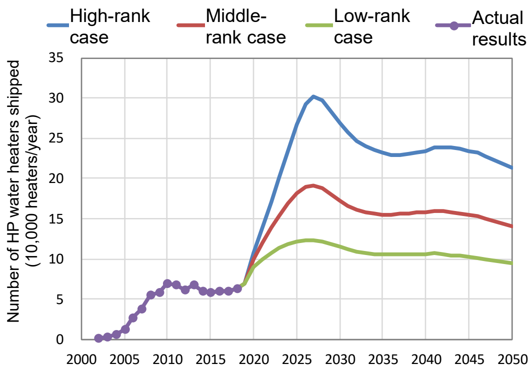


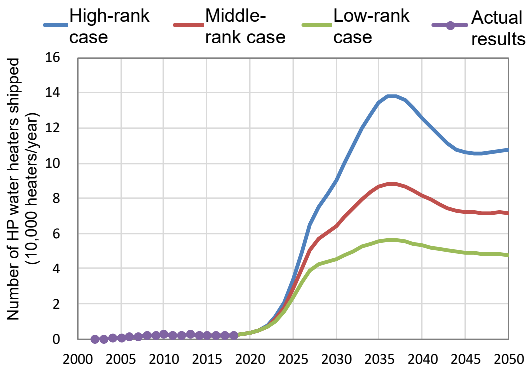
Fig. 2-10 stimation results of the number of stock of residential HP water heaters

(Reference) Number of residential HP water heaters shipped and number of stock by market segment

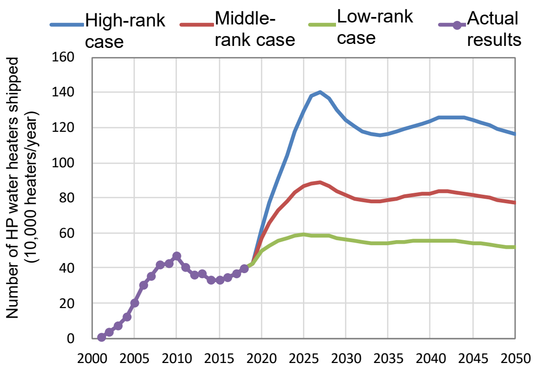
For reference, estimated results of the number of residential heat pump water heaters shipped and the number of stock by market segment in each case of high rank, middle rank, and low rank are shown in Fig. 2-11 and Fig. 2-12.



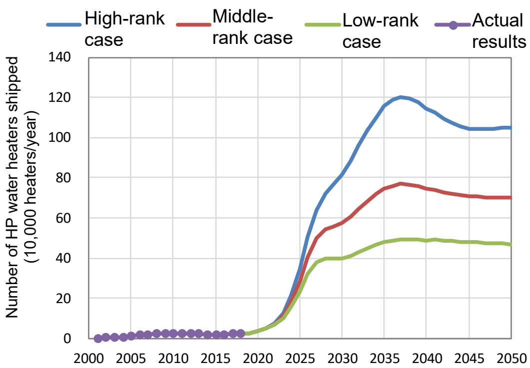
Market segment (1): Cold region, detached house



Market segment (2): Cold region, apartment house

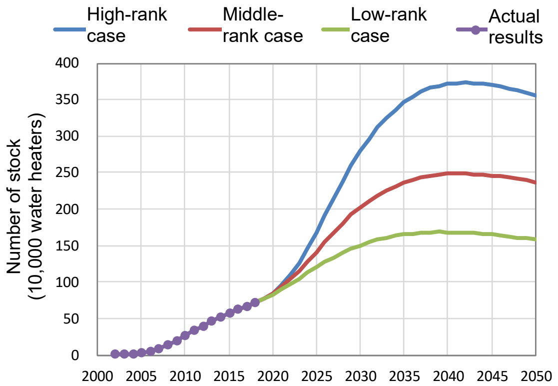


Market segment (3): Warm region, detached house

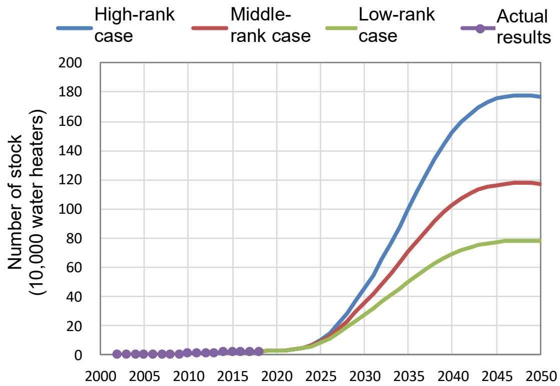


Market segment (4): Warm region, apartment house

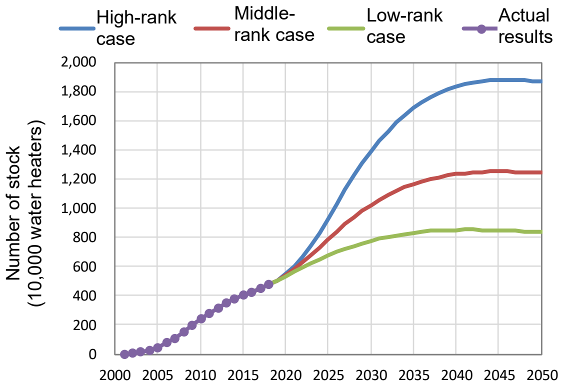
Fig. 2-11 The number of residential HP water heaters shipped by market segment



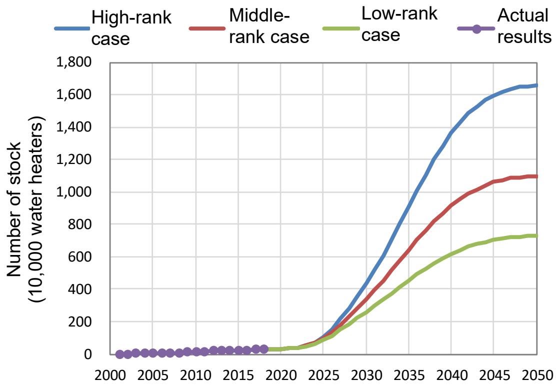
Market segment (1): Cold region, detached house



Market segment (2): Cold region, apartment house



Market segment (3): Warm region, detached house



Market segment (4): Warm region, apartment house

Fig. 2-12 The number of stock of residential HP water heaters by market segment

(2) Primary energy consumption, energy-saving effects, and CO2 reduction effects

Fig. 2-13 shows the results of calculating the primary energy consumption on the basis of the number of residential HP water heaters shipped, number of stock, flow efficiency, yearly load per water heater, and primary energy conversion factor.

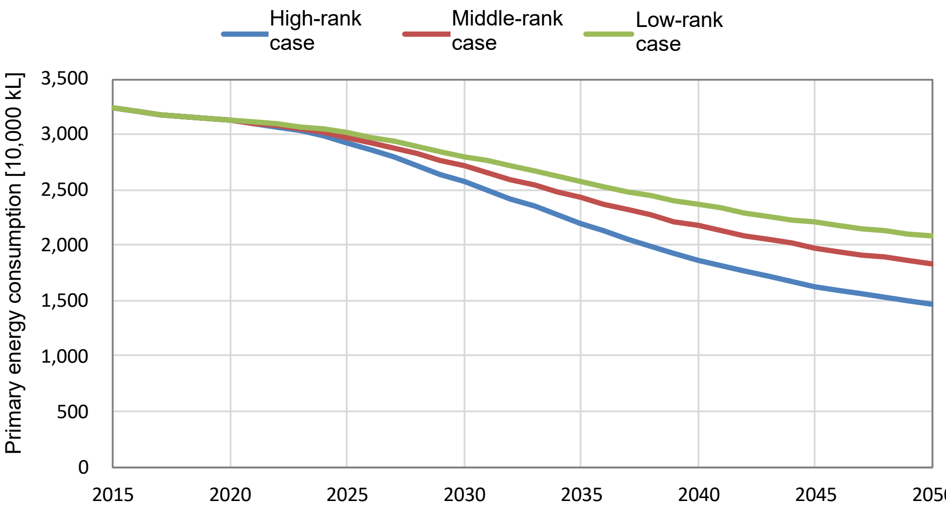


Fig. 2-13 Estimated results of primary energy consumption: Residential hot water supply

Based on the above-mentioned results, for each case, Fig. 2-14 and Fig. 2-15 show the energy-saving effect (primary energy consumption reduction effect) achieved from the current fixed cases, in which the current (FY2018) stock share and flow efficiency of residential heat pump water heaters were assumed to be constant for a long time to come.

The energy-saving amount in the middle-rank case in 2050 is 6,320,000 kL/year, of which the substitution effect achieved by gas-fired water heaters, oil-fired water heaters, and electric water heaters is assumed to account for 3,590,000 kL/year, and the efficiency improvement effect of heat-pump water heaters is assumed to account for 2,740,000 kL/year.

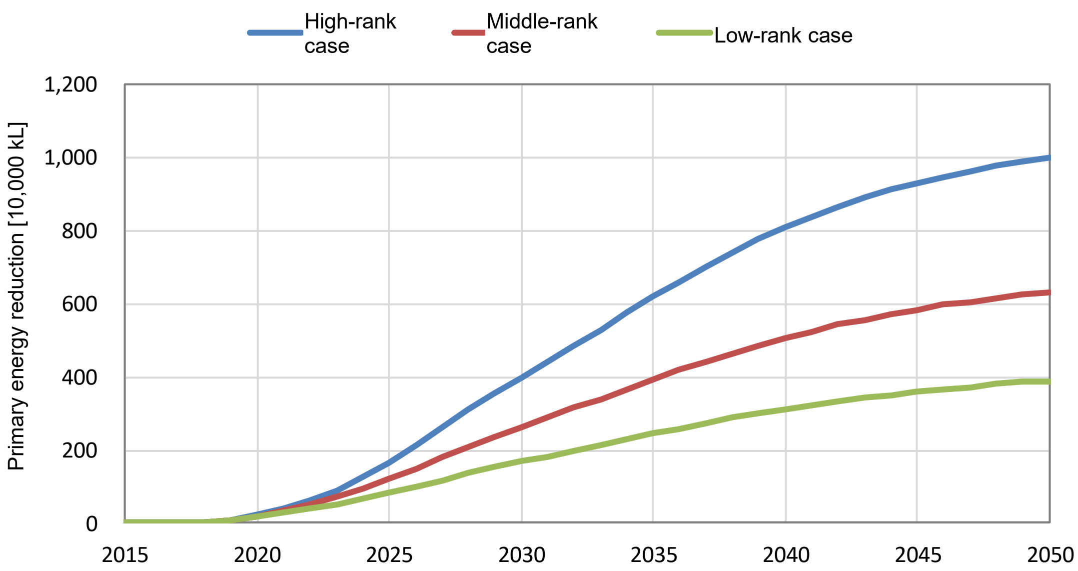


Fig. 2-14 Estimation result of energy-saving effect: Residential hot-water supply

Table 2-5 Breakdown of energy-saving effects: residential hot water supply

Case	Breakdown		Energy-saving effect (10,000 kL/year)			
			FY2020	FY2030	FY2040	FY2050
High-rank	Total		22	400	809	1,001
		Effects of substitution for other water heaters	21	318	546	589
		Efficiency improvement effect of HP water heaters	1	83	263	412
Middle-rank	Total		21	262	507	632
		Effects of substitution for other water heaters	19	205	332	359
		Efficiency improvement effect of HP water heaters	1	58	175	274
Low-rank	Total		18	168	312	390
		Effects of substitution for other water heaters	17	127	194	208
		Efficiency improvement effect of HP water heaters	1	41	118	183

Note) The total indicated as a total of each value does not always coincide due to round-off.

Fig. 2-15and Table 2-6 show the results of multiplying the above-mentioned energy-saving effect by the CO2 consumption rate to estimate CO2 reduction effect. The CO2 reduction effect in the middle-rank case in FY2050 is 18,780,000 t-CO2/year, of which the substitution effect of combustion-based water heaters is estimated to be 17,480,000 t-CO2/year and the heat pump water heater efficiency improvement effect to be 1,300,000 t-CO2/year.

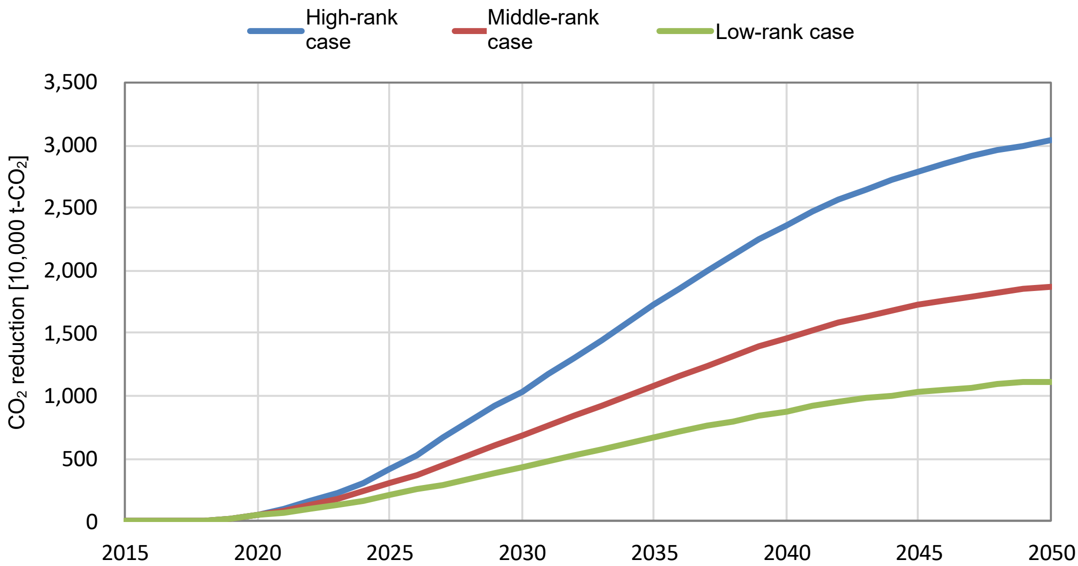


Fig. 2-15 Estimation results of CO2 reduction effect: Residential hot water supply

Table 2-6 Breakdown of CO2 reduction: Residential hot water supply

Case	Breakdown		CO2 reduction effect (10,000 t-CO2/year)			
			FY2020	FY2030	FY2040	FY2050
High-rank	Total		53	1,039	2,361	3,037
		Effects of substitution for other water heaters	50	917	2,106	2,840
		Efficiency improvement effect of HP water heaters	3	121	256	196
Middle-rank	Total		49	677	1,462	1,878
		Effects of substitution for other water heaters	46	592	1,292	1,748
		Efficiency improvement effect of HP water heaters	2	85	170	130
Low-rank	Total		44	428	877	1,116
		Effects of substitution for other water heaters	42	367	762	1,029
		Efficiency improvement effect of HP water heaters	2	61	115	87

Note) The total indicated as a total of each value does not always coincide due to round-off.

2.2 Residential air-conditioning

2.2.1 Prerequisites

(1) Air-conditioners targeted for evaluation

For residential air-conditioning, the evaluation was made on the effects of replacing gas space heaters and oil-fired space heaters with residential air-conditioners as well as on the effects of increasing the efficiency of residential air-conditions in space cooling applications. The residential air-conditioners shown in Table 2-7 were subject to the evaluation. Electrical carpets, kotatsu, and electric space heaters were not subject to the evaluation.

"Residential air-conditioners" are defined as those whose actual shipment track record is indicated in the self-statistics of JRAIA. The gas and oil-fired space heaters whose shipment track record is shown in the self-statistics of JGKA were subject to the evaluation.

Table 2-7 Residential air-conditioners targeted for evaluation

Residential air-conditioners on analysis	Residential air-conditioners on the statistics	
	Statistics name	Targeted residential air-conditioners
Residential air-conditioners	Self-statistics of the Japan Refrigeration and Air Conditioning Industry Association (JRAIA)	Residential air-conditioners
Gas space heaters	Self-statistics of Japan Industrial Association of Gas and Kerosene Appliances (JGKA)	Gas-fired water heaters and space heaters dedicated for space heating
		Gas-fired space heaters
Oil-fired space heaters	Self-statistics of Japan Industrial Association of Gas and Kerosene Appliances (JGKA)	Oil-fired space heaters
		Open type forced ventilating oil burning space heater
		Semi-closed type oil burning space heater
		Closed type oil burning space heater
		Oil-fired space heater for floor heating

(2) Setting of market segments

Since the market of residential heat pump water heaters varies according to residential properties, the home water heater market was divided into four segments of (1) through (4) as shown in Table 2-8. The regional classification was defined as follows:

- Cold region: Hokkaido, Tohoku District (Aomori Prefecture, Iwate Prefecture, Miyagi Prefecture, Akita Prefecture, Yamagata Prefecture, and Fukushima Prefecture), and Hokuriku District (Niigata Prefecture, Toyama Prefecture, Ishikawa Prefecture, and Fukui Prefecture)
- Warm region: Areas other than those mentioned above.

Table 2-8 Segment setting of residential air-conditioning market

Classification	Region	Type of houses
(1)	Cold region	Detached house
(2)	Cold region	Apartment house
(3)	Warm region	Detached house
(4)	Warm region	Apartment house

2.2.2 Calculation flow

Fig. 2-16 shows the calculation flow of residential air conditioner diffusion prospects in the domestic air conditioning market.

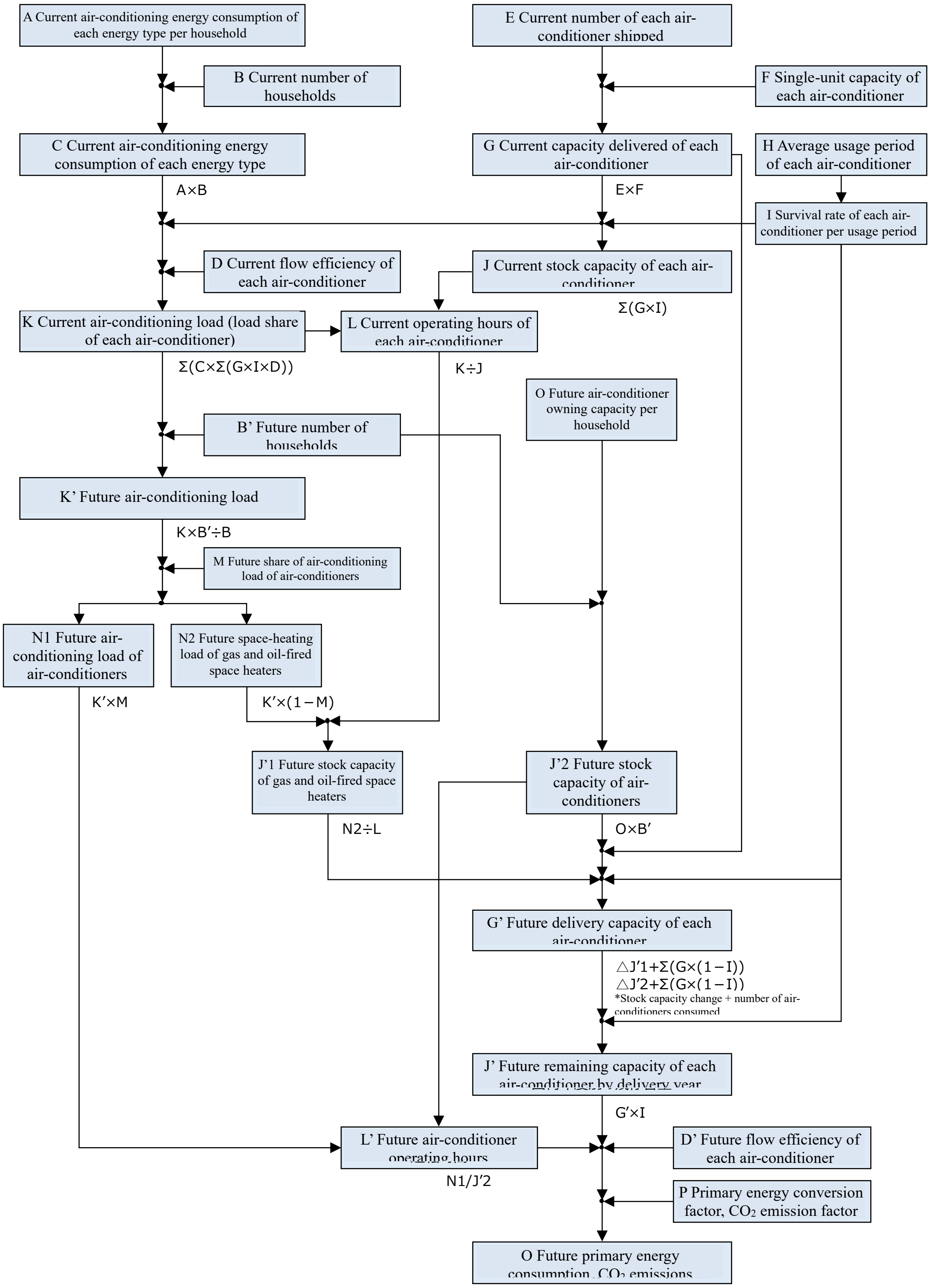


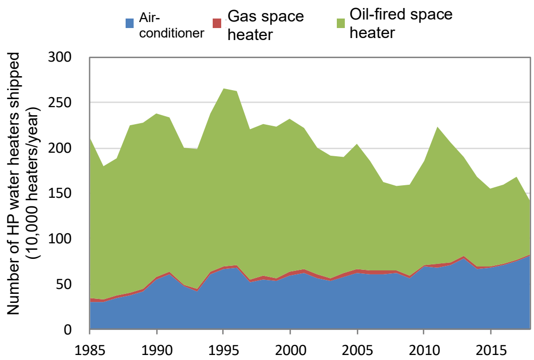
Fig. 2-16 Calculation flow of residential air-conditioners

2.2.3 Data used for calculation

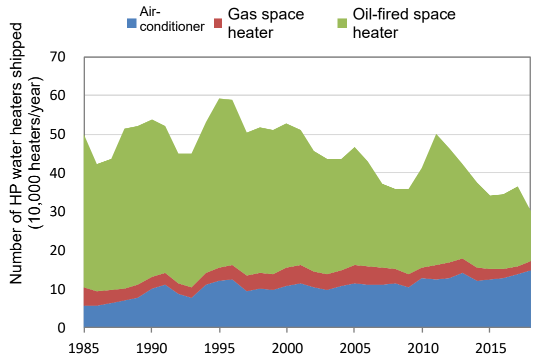
(1) Market size of residential air-conditioners

1) The number of residential air-conditioners shipped

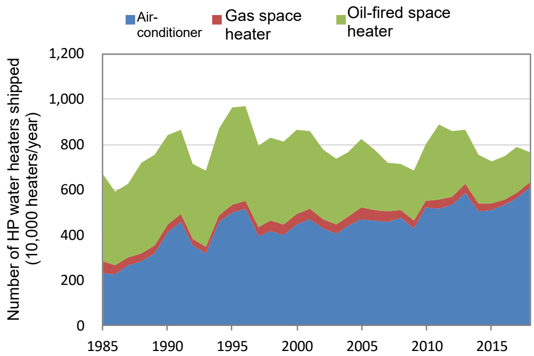
Fig. 2-17 shows changes in the number of residential air-conditioners shipped domestically. When the number of residential air-conditioners shipped domestically is viewed, in the cold region, the ratio of kerosene heaters is high, whereas in the warm region, the ratio of air-conditioners is high.



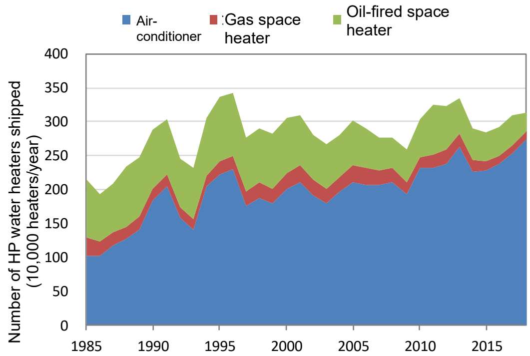
Market segment (1): Cold region, detached house



Market segment (2): Cold region, apartment house



Market segment (3): Warm region, detached house



Market segment (4): Warm region, apartment house

Fig. 2-17 Changes in the number of residential air conditioners shipped

Source) "Changes in numbers of residential air-conditioners shipped domestically and abroad," the Japan Refrigeration and Air Conditioning Industry Association (JRAIA), "Sales Results and Forecast of Gas and Kerosene Appliances," Japan Industrial Association of Gas and Kerosene Appliances (JGKA), "Yearbook of machinery statistics," Ministry of Economy, Trade and Industry (METI), "Survey and National Test Survey related to Estimation of CO2 emissions from household," Ministry of Environment (MOE), and others.

The number of residential air-conditioners shipped across Japan was set from the self-statistics of JRAIA. The number of gas and oil space heaters shipped across Japan was set from the self-statistics of JGKA and the data of Gas and Oil-fired Water Heaters Judgment Criteria Working Group. The equipment category whose information at the past time point is unable to be obtained was estimated by applying the rate of change with time, etc. of the number of equipment sold of the relevant category obtained from " Yearbook of machinery statistics" (METI).

The breakdown of the number of residential air conditioners shipped by cold region and warm region, as well as by detached house and apartment house, was estimated by assuming that it was equal to the breakdown of the number of residential air-conditioners used by market segment of each equipment obtained from “Survey and National Test Survey related to Estimation of CO2 Emissions from Household,” (MOE).

2) Single-unit capacity of residential air-conditioners

The single-unit capacity of residential air-conditioners was set at a simple average of each fiscal year of lineups carried in the “Energy Conservation Performance Catalog” from FY1997 through FY2018. For FY2020 and after, the single-unit capacity was set to be constant at the FY2018 value and that before FY1996 was set to be constant at the FY1997 value.

The single-unit capacities of gas heaters and oil heaters were set to be constant using simple averages of lineups from FY2004 through FY2018 carried in the “Energy Conservation Performance Catalog” throughout the analysis period, because the simple averages by fiscal years of lineups from FY2004 through FY2018 carried in the Catalog went generally sideways.

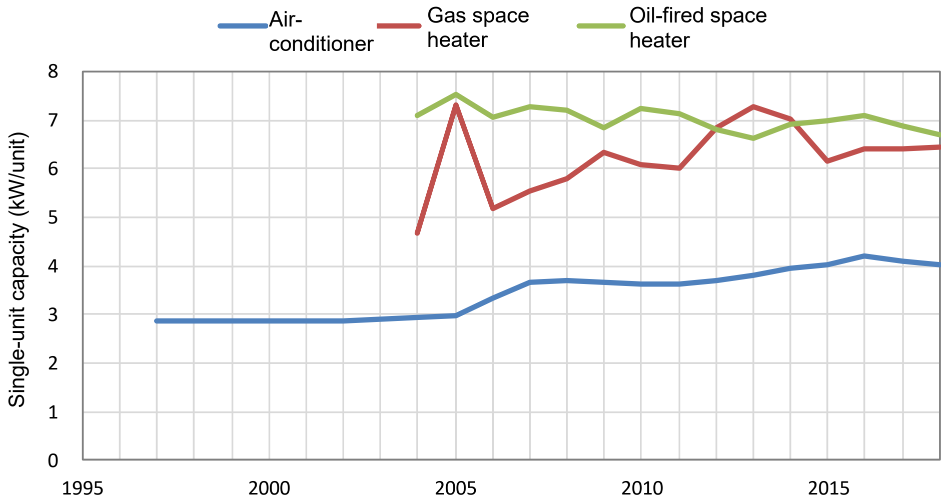


Fig. 2-18 Single-unit capacity of a residential air-conditioner

Source) “Energy Conservation Performance Catalog” (Agency for Natural Resources and Energy), etc.

3) Flow efficiency of residential air-conditioner

The flow efficiency of air-conditioning units by equipment was set as shown in Fig. 2-19.

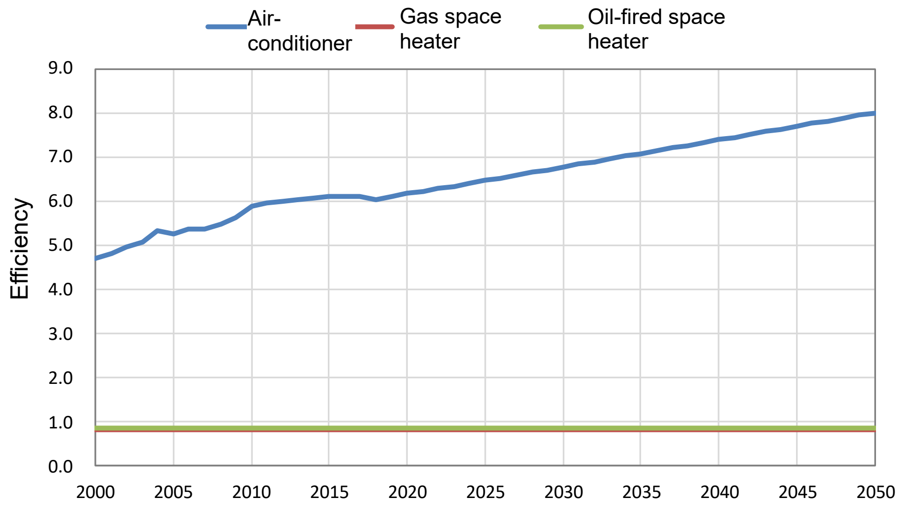


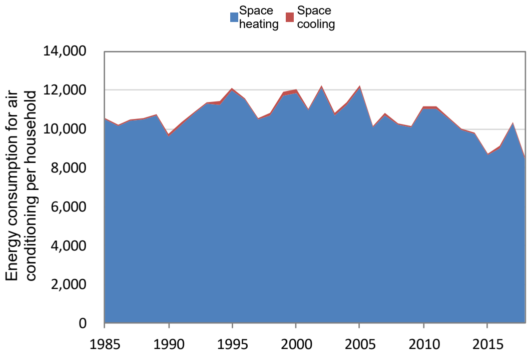
Fig. 2-19 Assumption of flow efficiency by residential air-conditioner

With respect to residential air-conditioners, the flow efficiency was set by determining the weighted average of the FY2018 number of residential air-conditioners shipped using the annual performance factor (APF) by capacity size of models carried in the “Energy Conservation Performance Catalog” (Agency for Natural Resources and Energy) for the period from FY2006 to FY2018. For the period from FY2000 to FY2005 where no APF existed, the rate of change with time of APF was set by presuming that it was 1/2 of the rate of change with time of the coefficient of performance (COP). For FY2050, the flow efficiency was set in such a manner that AFP is to improve to 8.0.

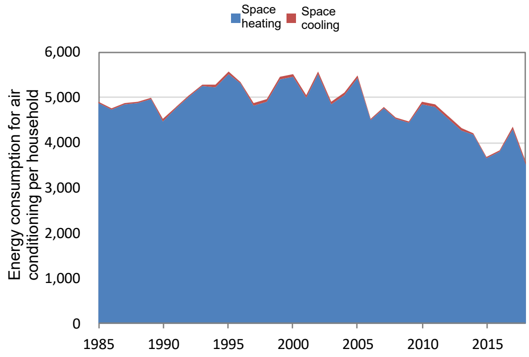
For gas space heaters and oil-fired space heaters, the flow efficiency was set by the simple average of models carried in the “Energy Conservation Performance Catalog” (Agency for Natural Resources and Energy). The oil-fired space heater adopted the average of forced-convection types, while the gas space heater adopted the average of all types.

4) Energy consumption for air-conditioning per household

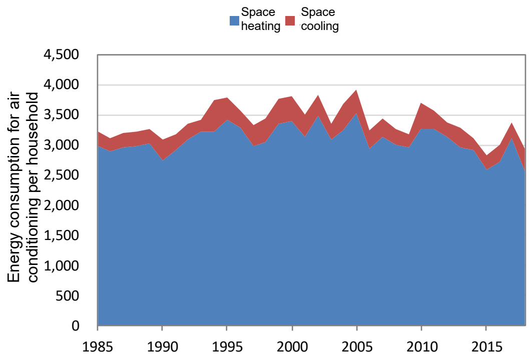
Fig. 2-20 shows changes in energy consumption for air conditioning per household (secondary energy base). In both cold and warm regions, per household energy consumption for air-conditioning is smaller for the apartment house than for the detached house.



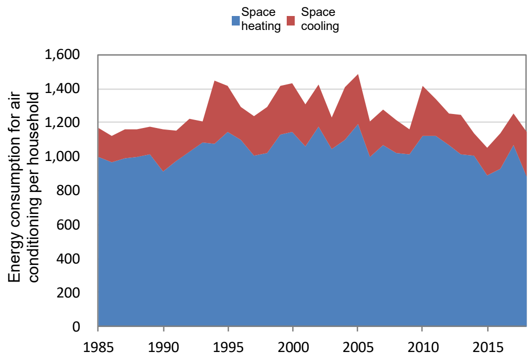
Market segment (1): Cold region, detached house



Market segment (2): Cold region, apartment house



Market segment (3): Warm region, detached house



Market segment (4): Warm region, apartment house

Fig. 2-20 Changes in energy consumption for air conditioning per household (secondary energy base)

Source) "EDMC Handbook of Japan's & World Energy & Economic Statistics" (EDMC IEE JAPAN) and "Survey and National Test Survey related to Estimation of CO2 Emissions from Household" (MOE).

The energy consumption for air conditioning per household was estimated on the basis of changes in energy consumption by energy type in "Handbook of Energy & Economic Statistics" and the air-conditioning energy consumption distribution per household by cold region and warm region and by detached house and apartment house of each energy category obtained from "Actual Statistical Survey of CO2 Emissions of Residential Sector."

5) Average usage period and survival curve of residential air-conditioners

The average usage period of residential air-conditioners was set to about 13.7 years, which is the average usage period of residential air-conditioners as of FY2019 in "Consumer Behavior Survey." For gas space heaters and oil-fired space heaters, about 11 years and about 10 years were adopted, respectively, which are average usage periods of gas space heaters and oil-fired space heaters in the "Survey of studies concerning energy-saving measures of equipment and instruments" (FY2015) (questionnaire results as of 2006 conducted by JGKA.

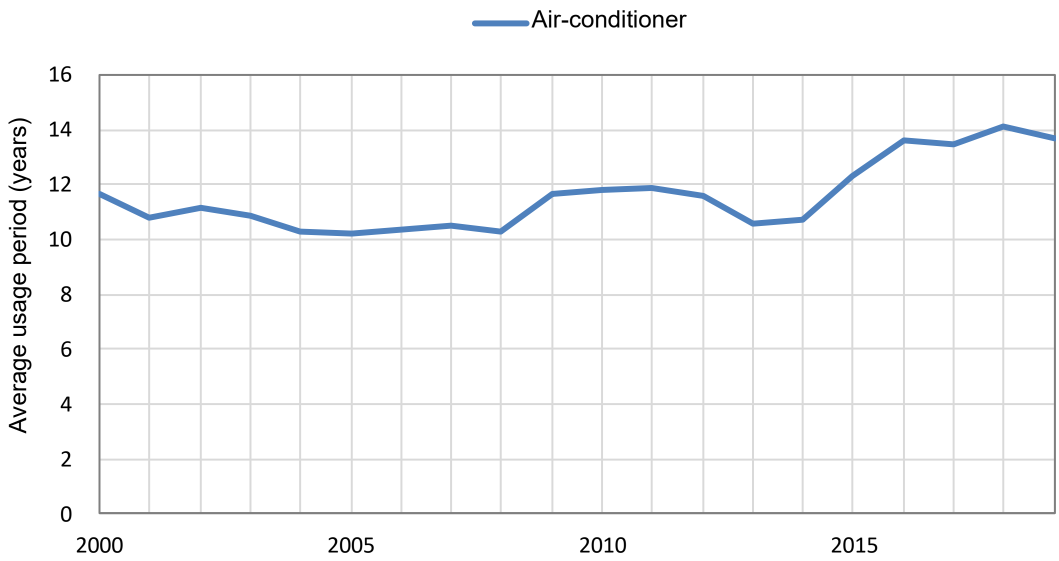


Fig. 2-21 Average usage period of residential air conditioners

Source) "Consumer Behavior Survey"

The survival curve (survival rate by usage periods) is given by the following formula. Parameters α and β that express the shape of the survival curve must be set. In the present case, settings were performed in such a manner that the average usage period of commercial water heaters assumed from the survival curve conformed to the assumption of the above-mentioned average usage period.

$$\text{Survival rate} = e^{-\alpha(elapsed\ years^{\beta})}$$

Fig. 2-22 shows the survival curve set as described above.

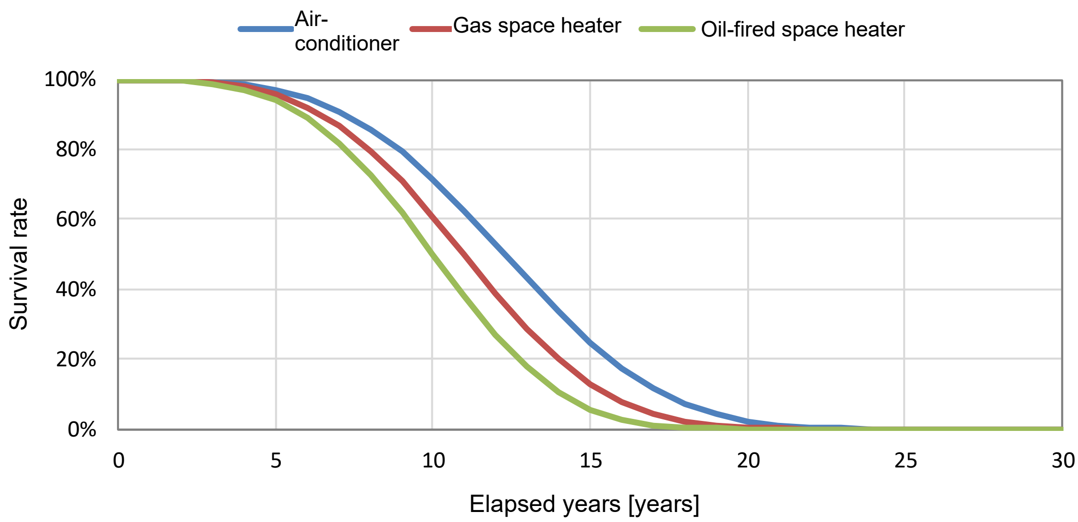


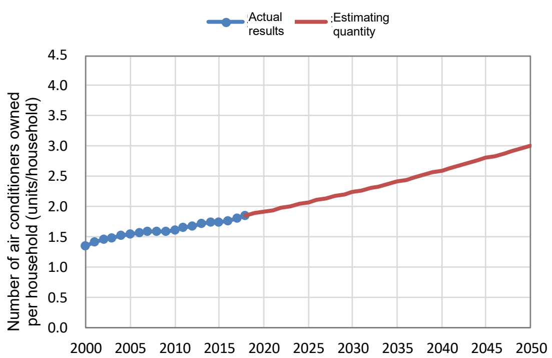
Fig. 2-22 Survival curve of residential air conditioners

6) Market size of residential air conditioners (air-conditioning load)

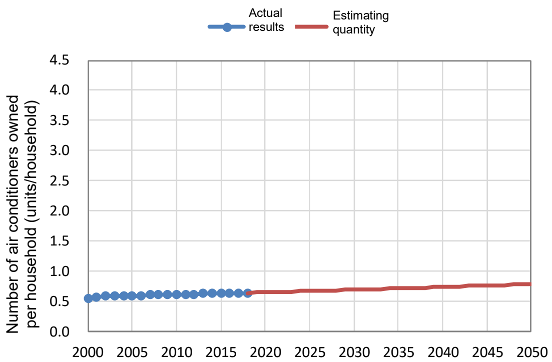
The air-conditioning load was estimated by multiplying the number of households by the air-conditioning load.

The current air-conditioning load per household was first estimated by multiplying the above-mentioned air-conditioning energy consumption per household by the stock efficiency of each air conditioner. The stock efficiency was estimated by estimating the remaining capacity share for every elapsed year by multiplying the above-mentioned number of residential air-conditioners shipped by the single-unit capacity and survival rate, and by multiplying the product by the yearly flow efficiency.

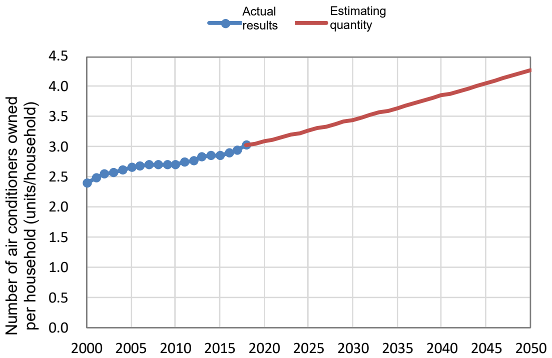
Next, with respect to the future air-conditioning load per household, the space heating load was set unchanged from the current conditions. At the same time, the space cooling load was set to be proportional to the number of air conditioners owned per household. The future number of air conditioners owned per household was set as shown in Fig. 2-23 by estimating the current number of air-conditioners owned per household from the actual quantity shipped and applying logistic regression to the changing conditions.



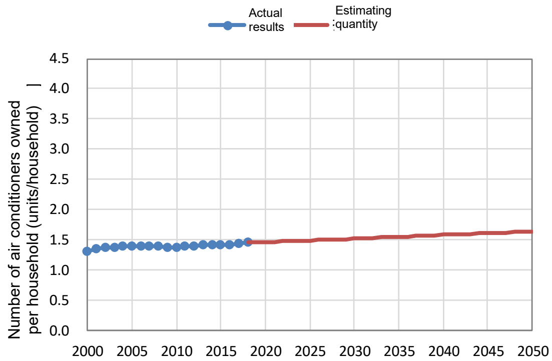
Market segment (1): Cold region, detached house



Market segment (2): Cold region, apartment house



Market segment (3): Warm region, detached house

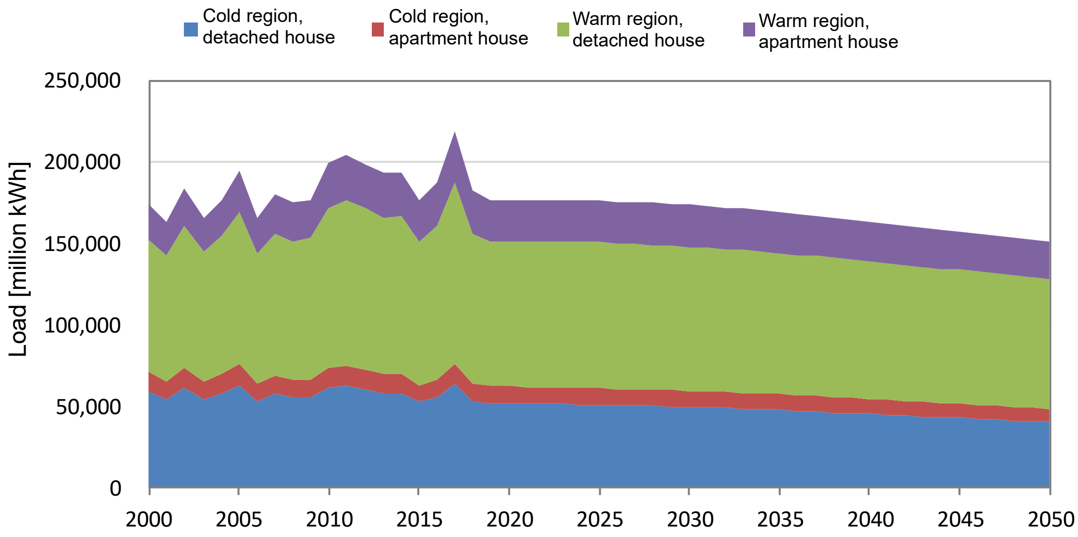


Market segment (4): Warm region, apartment house

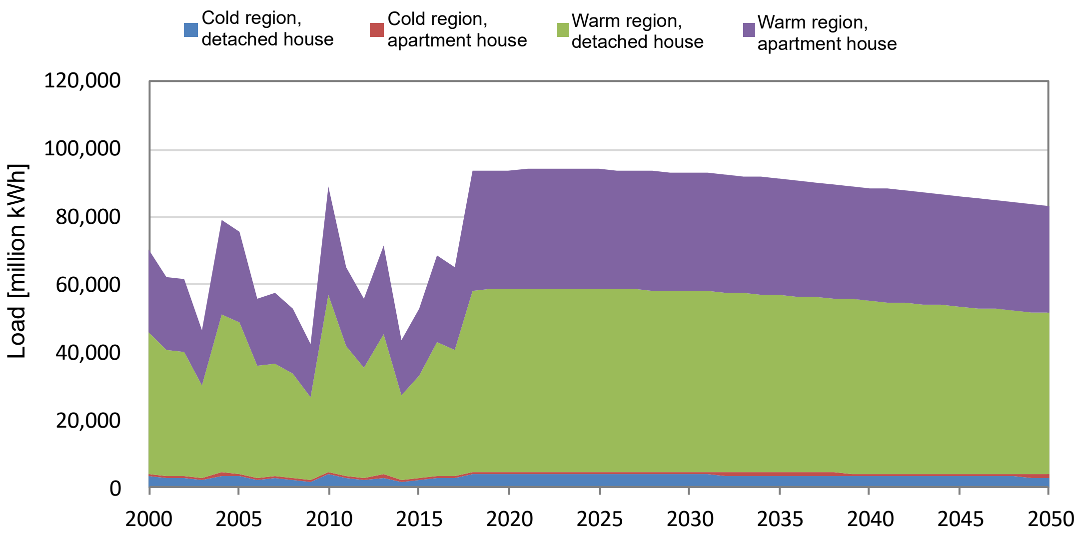
Fig. 2-23 Changes in the number of residential air conditioners owned per household

The future number of households was estimated from Projection of the Number of Households for Japan compiled by National Institute of Population and Social Security Research and " Housing and Land Survey" as in the case of setting in residential hot water supply of Section 2.1.

Fig. 2-24 shows the air-conditioning load estimated by multiplying the air-conditioning load per household set as above by the number of household.



Space heating load



Space cooling load

Fig. 2-24 Changes in residential air-conditioning load

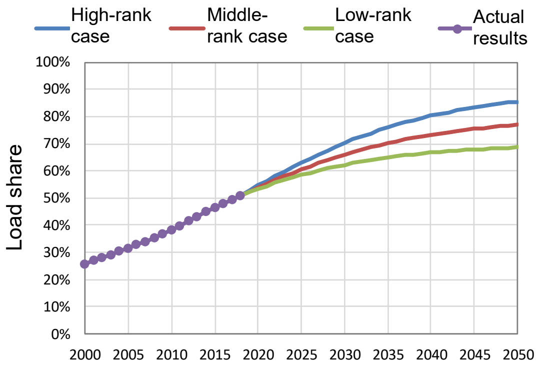
(2) Space-heating load share of residential air-conditioners

The load share of residential air-conditioners in the residential space heating market was projected by estimating the current load share of residential air-conditioners from actual space-heating energy consumption by energy type and the actual flow efficiency by air-conditioner, and then, by applying the logistic curve to the changing conditions. To apply the logistic regression, as shown in Table 2-9, three cases of high-rank, middle-rank, and low-rank were assumed as upper-limit asymptotic values of shares of residential air-conditioners. The shares of residential air-conditioners were assumed to approach the upper-limit asymptotic values in about FY2050 when products go through just about 3 product life cycles.

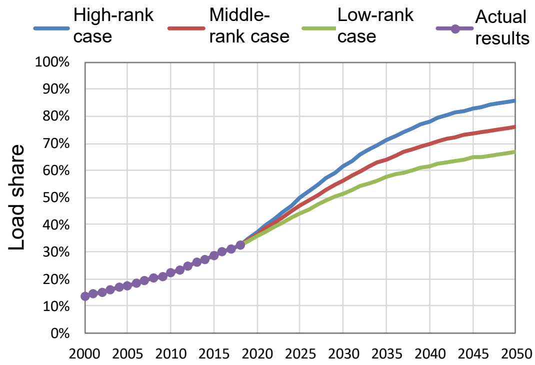
Table 2-9 Assumption of upper limit of thermal load share of residential air-conditioners in the residential heating market

Case	Upper introduction limit of air-conditioners (upper limit of thermal load share for space heating)
High-rank	Thermal load for space heating of each market segment x 90%
Middle-rank	Thermal load for space heating of each market segment x 80%
Low-rank	Thermal load for space heating of each market segment x 70%

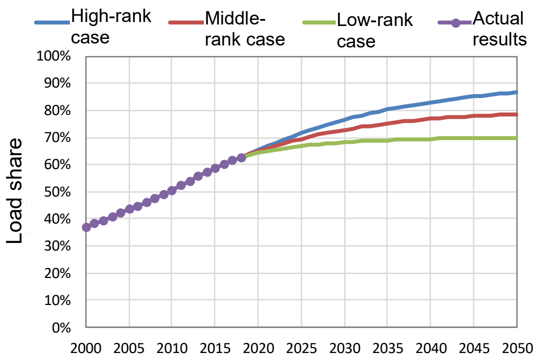
Fig. 2-25 shows the future load share of residential air-conditioners in the residential space heating market estimated on the basis of the foregoing assumption.



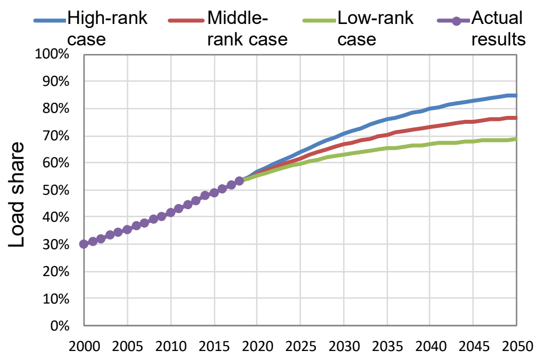
Market segment (1): Cold region, detached house



Market segment (2): Cold region, apartment house



Market segment (3): Warm region, detached house



Market segment (4): Warm region, apartment house

Fig. 2-25 Assumption of future load share of residential air-conditioners in the residential space heating market

2.2.4 Calculation results

(1) Delivery capacity and stock capacity

The estimation results of delivery capacity and stock capacity of residential air-conditioners based on the above-mentioned assumption are shown in Fig. 2-26 and Fig. 2-27, respectively.

The delivery capacity and diffusion capacity of residential air-conditioners are set on the basis of the number of air-conditioners owned per household, single-unit capacity, and number of households, but since the common settings are provided for all three cases, results of delivery capacity and diffusion capacity remain same irrespective of the cases.

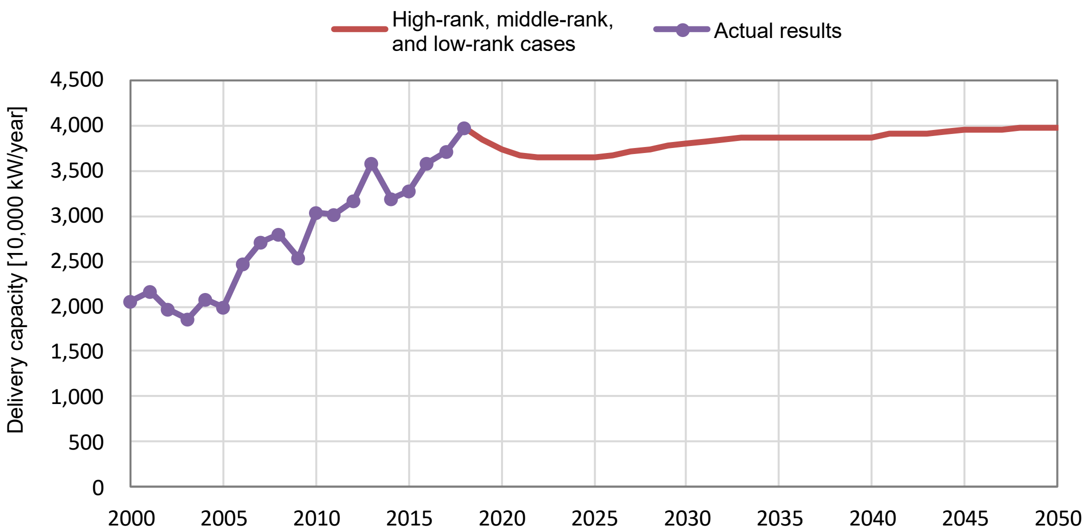


Fig. 2-26 Estimation results of residential air-conditioner delivery capacity

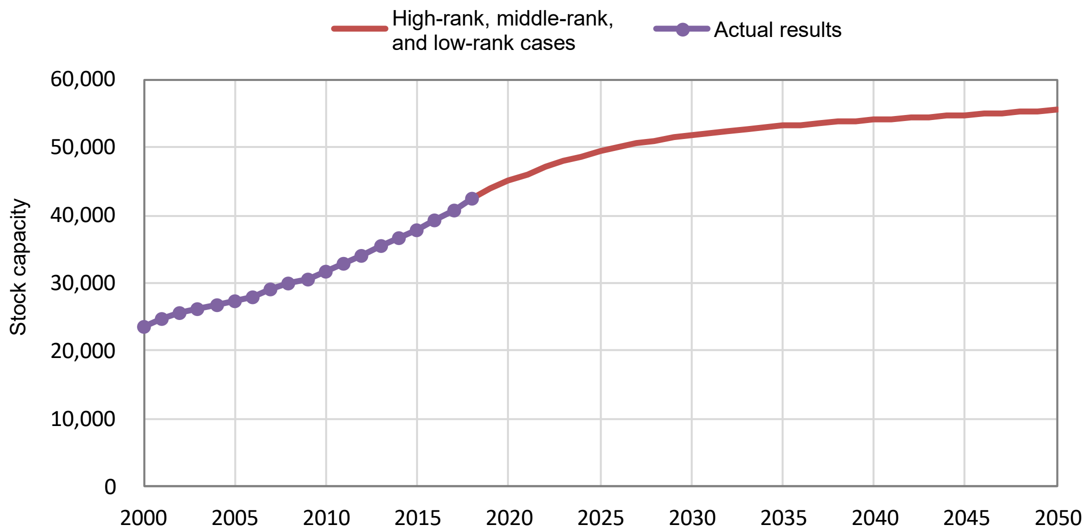
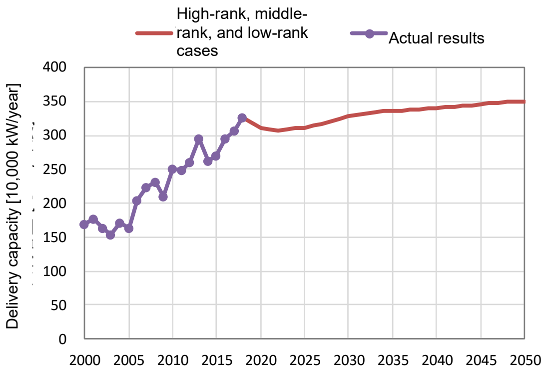


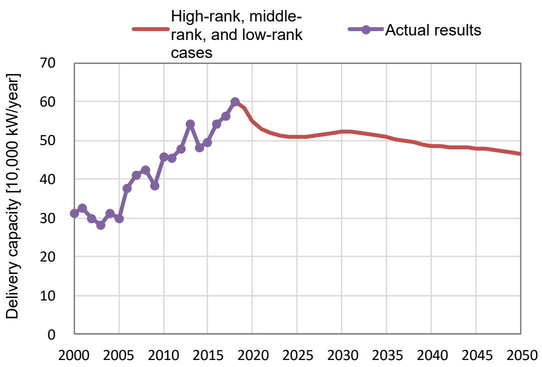
Fig. 2-27 Estimation results of residential air-conditioner stock capacity

(Reference) Delivery capacity by market segment

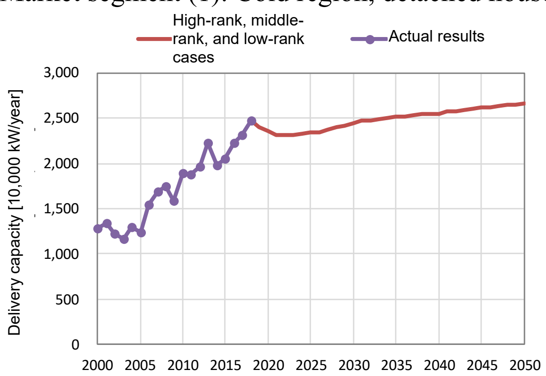
For reference, estimated results of residential air-conditioner delivery capacity and stock capacity in each case of high rank, middle rank, and low rank are shown in Fig. 2-28 and Fig. 2-29.



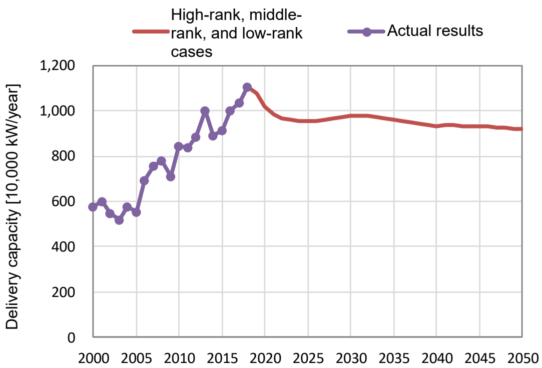
Market segment (1): Cold region, detached house



Market segment (2): Cold region, apartment house

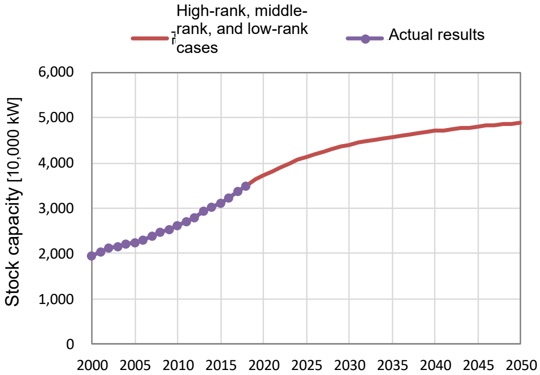


Market segment (3): Warm region, detached house

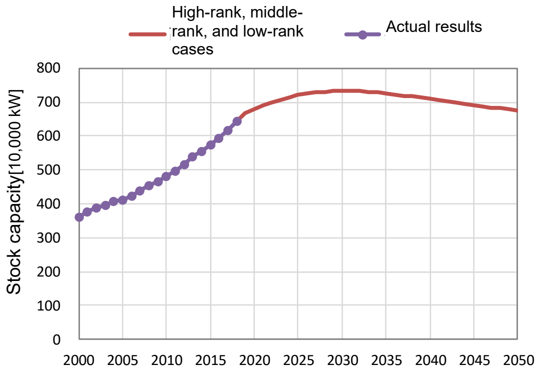


Market segment (4): Warm region, apartment house

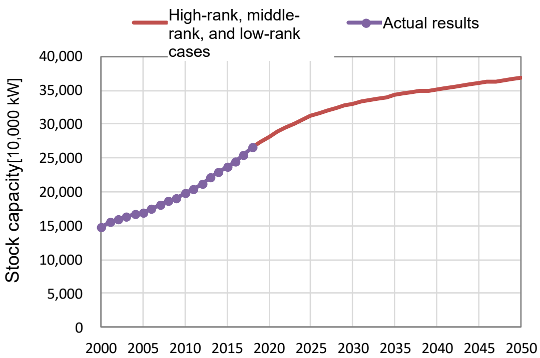
Fig. 2-28 Residential air-conditioner delivery capacity by market segment



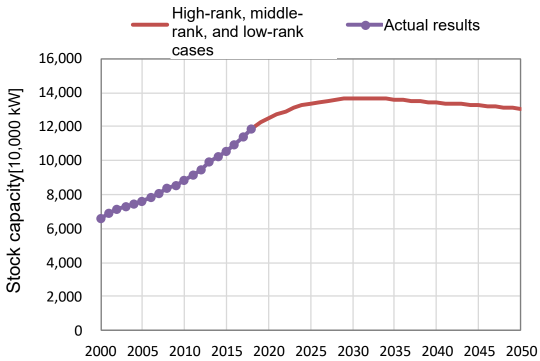
Market segment (1): Cold region, detached house



Market segment (2): Cold region, apartment house



Market segment (3): Warm region, detached house



Market segment (4): Warm region, apartment house

Fig. 2-29 Residential air-conditioner stock capacity by market segment

(2) Primary energy consumption, energy-saving effect, and CO2 reduction effect

Fig. 2-30 and Fig. 2-31 show results of calculating the primary energy consumption on the basis of the number of residential air-conditioners shipped, stock capacity, flow efficiency, and equivalent full-load hours of operation, and primary energy conversion factor of electric power.

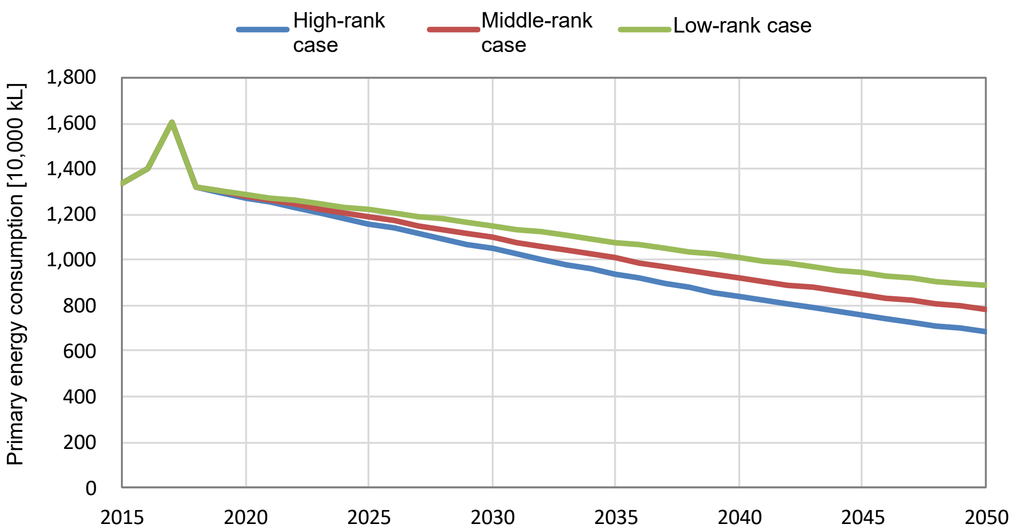


Fig. 2-30 Estimation results of primary energy consumption: Residential air-conditioning (for space heating)

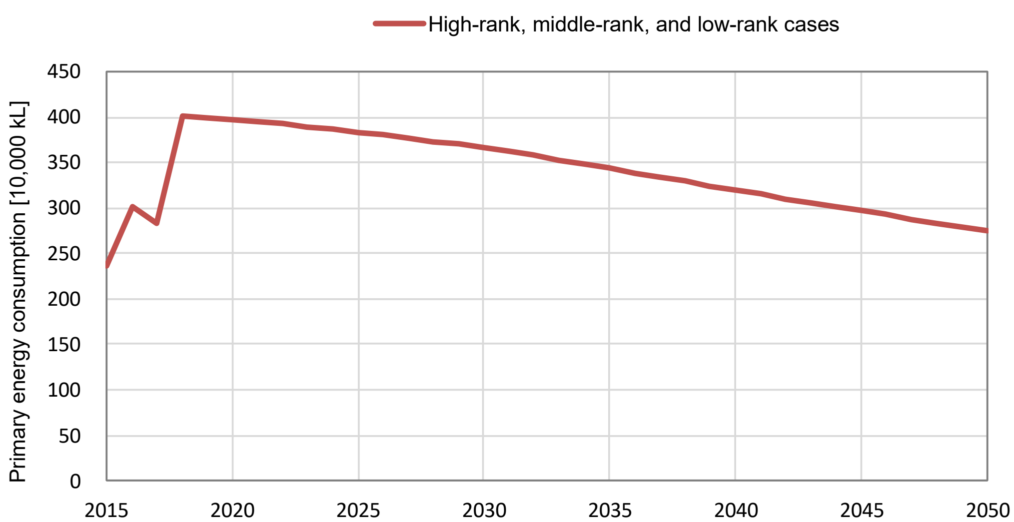


Fig. 2-31 Estimation results of primary energy consumption: Residential air-conditioning (for space cooling)

Based on the above-mentioned results, for each case, Fig. 2-32, Fig. 2-33, and Table 2-10 show the energy-saving effect (primary energy consumption reduction effect) achieved from current fixed cases, in which current (FY2018) load share and flow efficiency of residential air-conditioners were assumed to be constant for a long time to come.

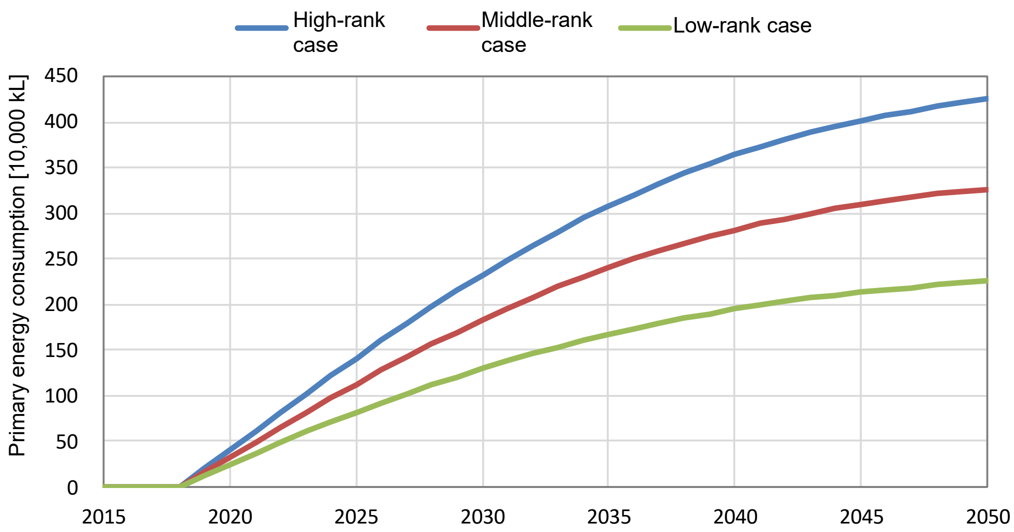


Fig. 2-32 Estimation results of energy-saving effect: Residential air-conditioning (for space heating)

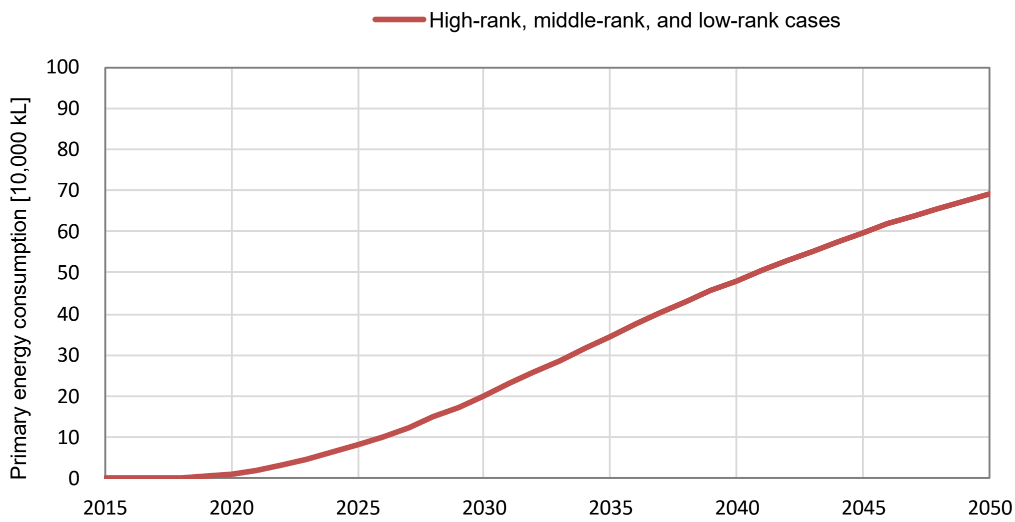


Fig. 2-33 Estimation results of energy-saving effect: Residential air-conditioning (for space cooling)

Table 2-10 Breakdown of energy-saving effect: Residential air-conditioning

Case	Breakdown		Energy-saving effect (10,000 kL/year)			
			FY2020	FY2030	FY2040	FY2050
High-rank	Total		42	252	412	494
		Effects of substitution for other space heaters	40	204	288	312
		Efficiency improvement effect of air-conditioners	2	49	124	182
	Space heating		41	232	363	425
		Effects of substitution for other space heaters	40	204	288	312
		Efficiency improvement effect of air-conditioners	1	29	75	113
	Space cooling		1	20	48	69
		Efficiency improvement effect of air-conditioners	1	20	48	69
Middle-rank	Total		34	203	330	396
		Effects of substitution for other space heaters	32	156	212	225
		Efficiency improvement effect of air-conditioners	2	47	117	171
	Space heating		33	183	282	327
		Effects of substitution for other space heaters	32	156	212	225
		Efficiency improvement effect of air-conditioners	1	27	69	102
	Space cooling		1	20	48	69
		Efficiency improvement effect of air-conditioners	1	20	48	69
Low-rank	Total		26	149	243	294
		Effects of substitution for other space heaters	24	104	132	134
		Efficiency improvement effect of air-conditioners	2	45	111	160
	Space heating		25	129	195	225
		Effects of substitution for other space heaters	24	104	132	134
		Efficiency improvement effect of air-conditioners	1	25	63	91
	Space cooling		1	20	48	69
		Efficiency improvement effect of air-conditioners	1	20	48	69

Note) The total indicated as a total of each value does not always coincide due to round-off.

Fig. 2-34, Fig. 2-35, and Table 2-11 show the results of CO2 reduction effect estimated by multiplying the above-mentioned energy-saving effect by the CO2 consumption rate. The CO2 reduction effect in the middle-rank case in FY2050 is 9,380,000 t-CO2/year, of which the substitution effect of other appliances is estimated to be 8,230,000 t-CO2/year and the residential air-conditioner efficiency improvement effect is estimated to be 1,150,000 t-CO2/year.

To speak about the space cooling, the CO2 reduction effect is anticipated to take a downward turn after increasing toward the latter half of the 2030s. This is because space cooling has no substitution by other appliances and is evaluated for the efficiency improvement of appliances using electric power (residential air-conditioners) only, and the influence of decreased CO2 reduction effect per unit energy-saving rate appears prominently as reduction of CO2 consumption rate of electric power proceeds in the medium to long term.

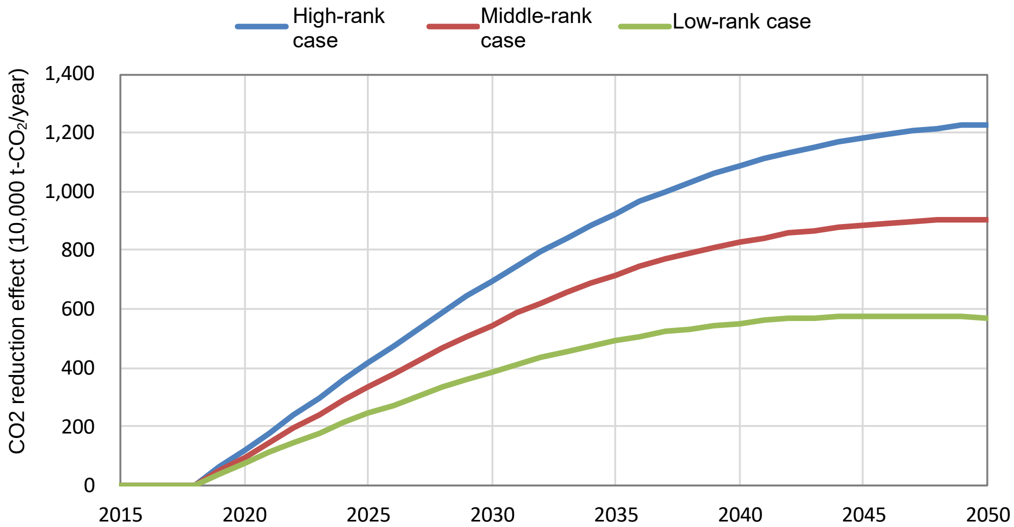


Fig. 2-34 Estimation results of CO2 reduction effect: Residential air-conditioning (for space heating)

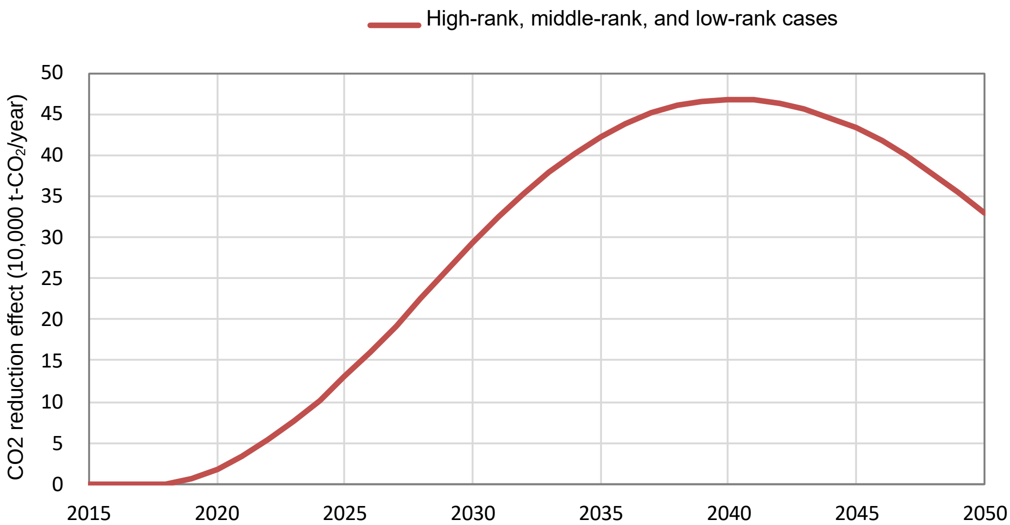


Fig. 2-35 Estimation results of CO2 reduction effect: Residential air-conditioning (for space cooling)

Table 2-11 Breakdown of CO_2 reduction effect: Residential air-conditioning

Case	Breakdown		CO2 reduction effect (10,000 t-CO2/year)			
			FY2020	FY2030	FY2040	FY2050
High-rank	Total		121	723	1,135	1,263
		Effects of substitution for other space heaters	115	622	968	1,143
		Efficiency improvement effect of air-conditioners	6	101	167	120
	Space heating		119	694	1,088	1,230
		Effects of substitution for other space heaters	115	622	968	1,143
		Efficiency improvement effect of air-conditioners	4	71	120	87
	Space cooling		2	29	47	33
		Efficiency improvement effect of air-conditioners	2	29	47	33
Middle-rank	Total		98	575	874	938
		Effects of substitution for other space heaters	92	477	713	823
		Efficiency improvement effect of air-conditioners	6	99	161	115
	Space heating		96	546	828	905
		Effects of substitution for other space heaters	92	477	713	823
		Efficiency improvement effect of air-conditioners	4	69	114	82
	Space cooling		2	29	47	33
		Efficiency improvement effect of air-conditioners	2	29	47	33
Low-rank	Total		76	414	599	602
		Effects of substitution for other space heaters	70	318	444	492
		Efficiency improvement effect of air-conditioners	6	96	155	109
	Space heating		74	385	552	569
		Effects of substitution for other space heaters	70	318	444	492
		Efficiency improvement effect of air-conditioners	4	67	108	76
	Space cooling		2	29	47	33
		Efficiency improvement effect of air-conditioners	2	29	47	33

Note) The total indicated as a total of each value does not always coincide due to round-off.

2.3 Commercial hot-water supply

2.3.1 Prerequisites

(1) Water heaters targeted for evaluation

With respect to commercial water heaters, combustion water heaters are evaluated for the effects achieved by substituting heat-pump water heaters for them, and commercial water heaters shown in Table 2-12 were subject to the evaluation.

The heat-pump water heater was defined as the "commercial heat-pump water heater" whose actual shipment track record is indicated in the self-statistics of JRAIA. The combustion water heater whose shipment track record is shown in the "Heater Almanac" of JHIA and self-statistics of JGKA were subject to the evaluation.

It was assumed that 50% of small once-through boilers were used for commercial hot water supply and the remaining 50% for industrial warming in the light of the assumption in the reports of METI's 2014 Projects for Promoting a Rational Use of Energy (Survey on energy-saving technologies in industrial furnaces, etc.). In the same manner, 7.5% of counter type storage gas water heaters, storage type closed vessel gas water heaters, and small-size oil-fired water heaters were assumed to be used commercial hot water supply and the remaining 92.5% for residential hot water supply with reference to the assumption in the same documents.

Table 2-12 Commercial water heaters targeted for evaluation

<table>
<tr><th rowspan="2">Water heaters on analysis</th><th colspan="2">Water heaters on the statistics</th></tr>
<tr><th>Statistics name</th><th>Targeted water heaters</th></tr>
<tr><td>HP water heaters</td><td>Self-statistics of the Japan Refrigeration and Air Conditioning Industry Association (JRAIA)</td><td>Commercial heat pump water heaters</td></tr>
<tr><td rowspan="8">Combustion water heaters</td><td rowspan="4">Heater Almanac of Japan Heating Industrial Association (JHIA.)
Self-statistics of Japan Industrial Association of Gas and Kerosene Appliances (JGKA)</td><td>Gas-fired hot-water boilers for commercial use</td></tr>
<tr><td>Oil-fired hot-water boilers exceeding 34.9 kW</td></tr>
<tr><td>50% of small once-through boilers</td></tr>
<tr><td>Vacuum type and atmospheric hot water generators</td></tr>
<tr><td rowspan="4">Heater Almanac of Japan Heating Industrial Association (JHIA.)</td><td>End stop system instantaneous gas water heaters for commercial use</td></tr>
<tr><td>7.5% of counter type storage gas water heaters</td></tr>
<tr><td>7.5% of storage type closed vessel gas water heater</td></tr>
<tr><td>7.5% of small-size oil-fired water heaters</td></tr>
</table>

(2) Market segment setting

Commercial heat-pump water heaters cannot always be introduced to all commercial buildings but suitability for introduction must be judged according to building applications and sizes.

Therefore, as with the past fiscal year survey, as shown in Table 2-13, the introduction suitability of commercial heat-pump water heaters was determined while getting hold of typical hot water supply systems presently used by building application and size.

Table 2-13 Introduction suitability evaluation of commercial HP water heaters by building segment

Building segment		Introduction suitability evaluation based on the current status of hot water supply system	
Offices	under 10,000 m^2	△	• Hot water is primarily in demand in lavatories and kitchenettes. In the past, there were methods of installing a boiler in a building and structure a hot-water supply piping, but presently, small water heaters or electric water heaters are popularly installed at places where hot water supply is needed, and therefore, it is often difficult to introduce HP water heaters. Large-size buildings exceeding 10,000 m^2, however, are frequently tenanted by cafeterias, restaurants and bars, and HP water heaters may be introduced.
	10,000 m^2 or more	○	
Stores	under 10,000 m^2	△	• Hot water is primarily in demand in lavatories and kitchenettes as in the case of offices and localized hot water supply plays a central role. Consequently, it is frequently the case that HP water heaters are difficult to be introduced, but in the case of large-scale stores or shopping centers, restaurants and bars may be frequently contained, and it is assumed that HP water heaters may be introduced.
	10,000 m^2 or more	○	
Restaurants and bars		○	• Great hot water demand is generated at kitchens, and gas water heaters or others are used. As with the residential types, hot water demand may be met by once-through-type heat-pump water supply systems.
Schools	Nursery schools	○	• Nursery schools always have kitchen facilities and a high demand for hot water. In the case of elementary, junior high and senior 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 in 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.
	Kindergartens	△	
	Elementary, junior high, and senior high schools	○	
	Universities	○	
	Other schools	△	
Hotels and Inns		○	• 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 that have hot water boilers and hot water tanks, and heat-pump water heaters can be introduced. • In the case of large-scale hotels in the center of the city, hot water is often used in kitchens for sterilization and drying and steam is used in linen rooms. And, steam boilers are used as heat sources in many cases. 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-scale hotels in the center of the city 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.

Building segment		Introduction suitability evaluation based on the current status of hot water supply system	
Hospitals		○	• 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 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 may 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 may be introduced in large-scale hospitals as well.
Others	Welfare institutions	○	• Hot water is required in kitchens, bathrooms and private rooms. Basically, such demand is met fully by central hot water supply systems 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 may be introduced.
	Beauty and hair dressing services	○	• 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 for beauty and hair dressing services are often used. It is easy to apply heat-pump water heaters as the temperature of hot water from their tanks is constant.
	Sport facilities	○	• Hot water is required at shower rooms, lavatories and heated swimming pools. Basically, such demand is met by central hot water supply systems 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.
	Golf courses	○	• 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. It is basic to meet fully such demand by central hot water supply systems that have hot water boilers and hot water tanks. Heat-pump water heaters can be introduced.
	Other than the above	△	• In buildings other than those mentioned above, hot water is required mainly in lavatories and office kitchenettes, and hot water is supplied mainly at local points. Therefore, it is considered difficult to introduce heat-pump water heaters in many cases.

Based on the above-mentioned introduction suitability evaluation, the commercial hot water supply market was divided into three segments (1) through (3) as shown in Table 2-14. The regional category was defined as follows:

- Cold region: Hokkaido, Tohoku District (Aomori Prefecture, Iwate Prefecture, Miyagi Prefecture, Akita Prefecture, Yamagata Prefecture, and Fukushima Prefecture) Hokuriku District (Niigata Prefecture, Toyama Prefecture, Ishikawa Prefecture, and Fukui Prefecture)
- Warm region: Regions other than the above

Table 2-14 Assumption of commercial hot water supply market segments

Market segment			Assumption
Class.	Building segment	Region	
(1)	Introduction suitability ○	Cold region	• It is assumed that present diffusion of commercial HP water heaters progresses for building segments with "○" introduction suitability. • However, since the diffusion gets delayed in the cold region from that in the warm region, introduction suitability was set in accordance with segments.
(2)	Introduction suitability ○	Warm region	
(3)	Introduction suitability △	--	• Building segments with "△" introduction suitability are applications difficult to meet demand by present commercial HP water heaters because localized water supply is popularly used. However, "downsizing" development is currently underway with focus on residential heat pumps. In the future, HP water heaters responding to localized hot water supply requirements, such as HP water heaters that can be installed under sinks, etc. may be put into practical use. • In this segment, these models were assumed to be introduced even in building segments with "△" introduction suitability in and after FY2025.

2.3.2 Calculation flow

Fig. 2-36 shows the calculation flow of heat pump water heater diffusion prospects in the commercial water heater market.

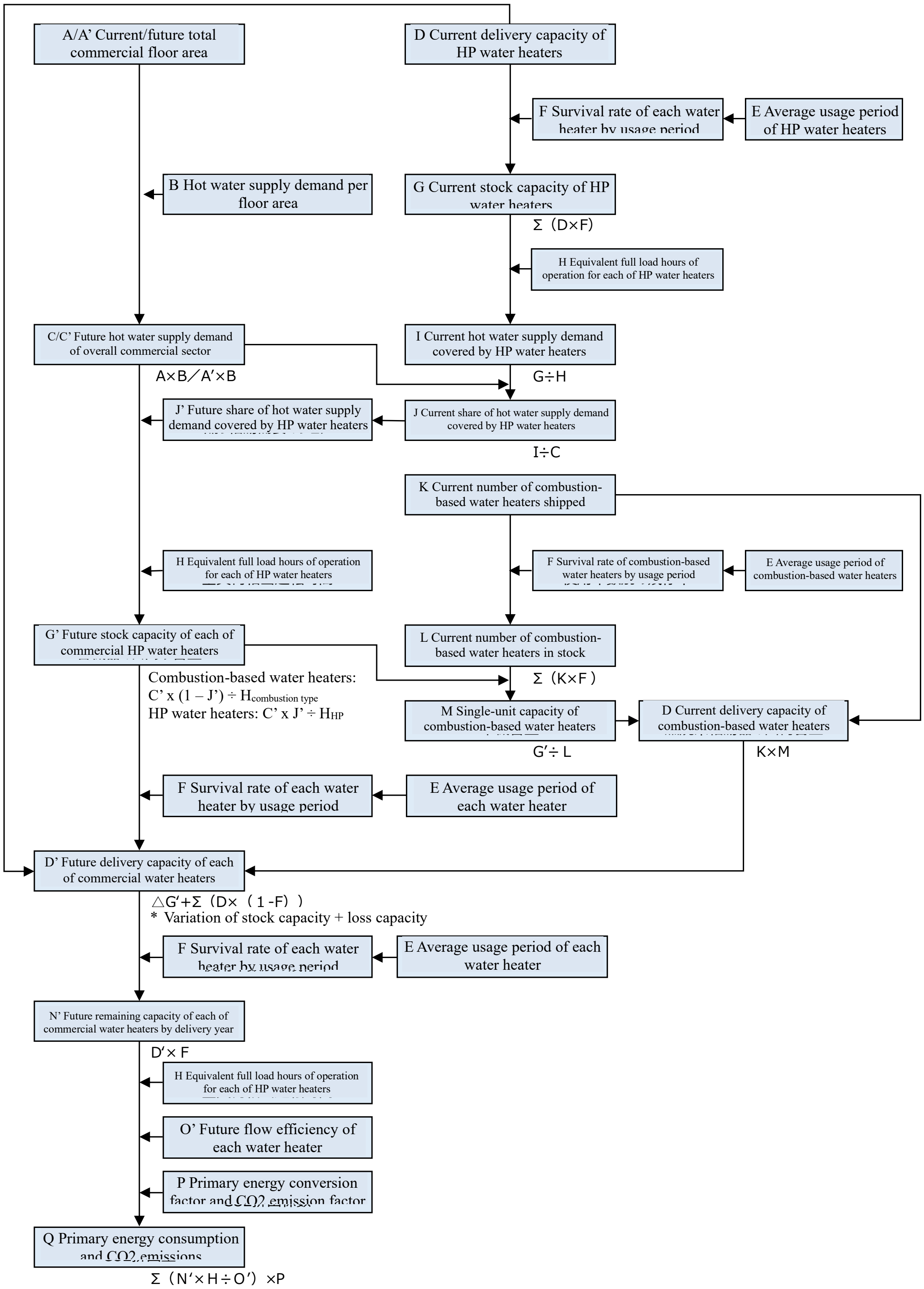


Fig. 2-36 Calculation flow of diffusion prospects of HP water heaters in commercial hot-water supply market

2.3.3 Data used for calculation

(1) Market size of commercial hot water supply (hot water supply demand in the commercial sector)

With respect to the present and future market size of commercial water supply (hot water supply demand in commercial sector), the hot water supply demand of the whole commercial sector was estimated by multiplying the total floor area of commercial buildings by the hot water supply demand per floor area.

1) Total commercial floor area by region and by building segment

In estimating the market size (stock capacity) of hot water supply for commercial use of present and future commercial sector, the total floor area of commercial buildings by region and by building segment was set straight.

The current (FY2018) actual value was broken down by region (cold region and warm region), building size, or still more detailed applications (in the case of schools, kindergarten, elementary, junior high, and senior high schools, universities, and the like) using various statistical data as shown in Table 2-16 in the following page, on the basis of the total floor area data by building applications stipulated in "EDMC Handbook of Japan's & World Energy & Economic Statistics" compiled by the Institute of Energy Economics, Japan, the Energy Data and Modelling Center.

Table 2-15 shows the estimation results of current total floor area for commercial use by region and building.

Table 2-15 Estimation results of current total commercial floor area by region and building

<table>
<tr><th colspan="2" rowspan="2">Building segment</th><th rowspan="2">Introduction suitability of HP water heaters</th><th colspan="3">Total floor area (million m²)</th></tr>
<tr><th>Whole country</th><th>Cold region</th><th>Warm region</th></tr>
<tr><td colspan="2">Total</td><td></td><td>1,904</td><td>340</td><td>1,563</td></tr>
<tr><td colspan="2">Offices</td><td></td><td>489</td><td>69</td><td>420</td></tr>
<tr><td></td><td>under 10,000 m²</td><td>△</td><td>329</td><td>46</td><td>283</td></tr>
<tr><td></td><td>10,000 m² or more</td><td>○</td><td>160</td><td>22</td><td>137</td></tr>
<tr><td colspan="2">Stores</td><td></td><td>491</td><td>91</td><td>400</td></tr>
<tr><td></td><td>under 10,000 m²</td><td>△</td><td>305</td><td>56</td><td>248</td></tr>
<tr><td></td><td>10,000 m² or more</td><td>○</td><td>186</td><td>34</td><td>152</td></tr>
<tr><td colspan="2">Restaurants and bars</td><td>○</td><td>69</td><td>11</td><td>58</td></tr>
<tr><td colspan="2">Schools</td><td></td><td>372</td><td>70</td><td>302</td></tr>
<tr><td></td><td>Nursery schools</td><td>○</td><td>25</td><td>4</td><td>21</td></tr>
<tr><td></td><td>Kindergartens</td><td>△</td><td>17</td><td>3</td><td>14</td></tr>
<tr><td></td><td>Elementary, junior high, and senior high schools</td><td>○</td><td>229</td><td>46</td><td>183</td></tr>
<tr><td></td><td>Universities</td><td>○</td><td>79</td><td>13</td><td>65</td></tr>
<tr><td></td><td>Other schools</td><td>△</td><td>23</td><td>4</td><td>19</td></tr>
<tr><td colspan="2">Hotels and inns</td><td>○</td><td>87</td><td>19</td><td>68</td></tr>
<tr><td colspan="2">Hospitals</td><td>○</td><td>120</td><td>22</td><td>98</td></tr>
<tr><td colspan="2">Others</td><td></td><td>276</td><td>58</td><td>217</td></tr>
<tr><td></td><td>Welfare institutions</td><td>○</td><td>60</td><td>11</td><td>49</td></tr>
<tr><td></td><td>Beauty and hair dressing services</td><td>○</td><td>14</td><td>3</td><td>11</td></tr>
<tr><td></td><td>Sport facilities</td><td>○</td><td>15</td><td>2</td><td>13</td></tr>
<tr><td></td><td>Golf courses</td><td>○</td><td>8</td><td>1</td><td>6</td></tr>
<tr><td></td><td>Other than the above</td><td>△</td><td>179</td><td>41</td><td>138</td></tr>
</table>

Table 2-16 How to set total floor area for commercial use by region and by building segment

	Building segment	Region			Remarks
		Whole country	Cold region	Warm region	
A	Total	EDMC total	(Total of A) x floor area in cold region ÷ floor area across the country	(Total of A) x floor area in warm region ÷ floor area across the country	The floor area by region is quoted from MLIT "Building Stock Statistics."
B	Offices	EDMC value of "Office"	(Total of B) x office floor area in cold region ÷ office floor area across the country	(Total of B) x office floor area in warm region ÷ office floor area across the country	The floor area of offices by region and size is quoted from MLIT "Corporations survey on land and buildings."
(1)	under 10,000 m^2	(Total of B) x floor area of offices under 10,000 m^2 ÷ floor area of offices across the country	(Total of B) x floor area of offices under 10,000 m^2 in cold region ÷ floor area of offices across the country	(Total of B) x floor area of offices under 10,000 m^2 in warm region ÷ floor area of offices across the country	
(2)	10,000 m^2 or more	(Total of B) x 10,000 m^2-plus floor area of offices ÷ floor area of offices across the country	(Total of B) x 10,000 m^2-plus floor area of offices in cold region ÷ floor area of offices across the country	(Total of B) x 10,000 m^2-plus floor area of offices in warm region ÷ floor area of offices across the country	
C	Stores	EDMC total of "wholesalers and retailers" and "department stores and supermarkets"	(Total of C) x floor area of stores in cold area ÷ floor area of stores across the country	(Total of C) x floor area of stores in warm area ÷ floor area of stores across the country	The floor area of stores by region and size is quoted from MLIT "Corporations survey on land and buildings."
(1)	under 10,000 m^2	(Total of C) x stores under 10,000 m^2 floor area ÷ floor area of stores across the country	(Total of C) x stores under 10,000 m^2 floor area of stores in cold region ÷ floor area of stores across the country	(Total of C) x stores under 10,000 m^2 floor area of stores in warm region ÷ floor area of stores across the country	
(2)	10,000 m^2 or more	(Total of C) x 10,000 m^2-plus floor area of stores ÷ floor area of stores across the country	(Total of C) x 10,000 m^2-plus floor area of stores in cold region ÷ floor area of stores across the country	(Total of C) x 10,000 m^2-plus floor area of stores in warm region ÷ floor area of stores across the country	
D	Restaurants and bars	EDMC value of "Restaurants and bars"	(Total of D) x number of restaurants and bars in cold region ÷ number of stores across the country	(Total of D) x number of restaurants and bars in warm region ÷ number of stores across the country	The number of restaurants and bars by region is quoted from the "2014 Economic Census for Business Frame."
E	Schools	EDMC value of "Schools"	Total of (1) to (5) of cold regions	Total of ① to ⑤ of warm regions	
(1)	Nursery schools	(Total of E) – (total of E (2) to (5))	(Total of E (1)) x number of nursery schools in cold region ÷ number of nursery schools across the country	(Total of E (1)) x number of nursery schools in warm region ÷ number of nursery schools across the country	The number of nursery schools by region is quoted from " Survey of Social Welfare Institutions."
(2)	Kindergartens	From " STATISTICAL ABSTRACT (education, culture, sports, science and technology)"	(Total of E (2)) x number of kindergartens in cold region ÷ number of kindergartens across the country	(Total of E (2)) x number of kindergartens in warm region ÷ number of kindergartens across the country	The number of schools by region is quoted from "STATISTICAL ABSTRACT."

	Building segment	Region			Remarks
		Whole country	Cold region	Warm region	
(3)	Elementary, junior high, and senior high schools	From “ STATISTICAL ABSTRACT (education, culture, sports, science and technology)”	(Total of E (3)) x number of elementary, junior high and senior high schools in cold region ÷ number of elementary, junior high and senior high schools across the country	(Total of E (3)) x number of elementary, junior high and senior high schools in warm region ÷ number of elementary, junior high and senior high schools across the country	
(4)	Universities	From “ STATISTICAL ABSTRACT (education, culture, sports, science and technology)”	(Total of E (4)) x number of universities in cold region ÷ number of universities across the country	(Total of E (4)) x number of universities in warm region ÷ number of universities across the country	
(5)	Other schools	From “ STATISTICAL ABSTRACT (education, culture, sports, science and technology)”	(Total of E (5)) x number of other schools in cold region ÷ number of other schools across the country	(Total of E (5)) x number of other schools in warm region ÷ number of other schools across the country	
F	Hotels and inns	EDMC values of “Hotels and Inns”	(Total of F) x floor area of hotels and inns in cold area ÷ floor area of restaurants and inns across the country	(Total of F) x floor area of hotels and inns in warm area ÷ floor area of restaurants and inns across the country	The floor area of hospitals and inns by region is quoted from MLIT “Corporations survey on land and buildings.”
G	Hospitals	EDMC values of “Hospitals”	(Total of G) x number of hospitals in cold region ÷ number of hospitals across the country	(Total of G) x number of hospitals in warm region ÷ number of hospitals across the country	The number of hospitals by region is quoted from “ Survey of Medical Institutions.”
H	Others	Total of EDMC “Others” and “Place of Amusement”	(Value of A in cold region) – (total of B through G in cold region)	(Value of A in warm region) – (total of B through G in warm region)	
(1)	Welfare institutions	Number of welfare institutions across the country x floor area per institution	Number of welfare institutions in cold region x floor area per institution	Number of welfare institutions in warm region x floor area per institution	The number of institutions of each application by region is quoted from the “2014 Economic Census for Business Frame.” The floor area of each application per institution is assumed as follows as in the case of past fiscal year surveys. Welfare institutions: 670 m^2 Beauty and hair dressing services: 50 m2 Sport facilities: 3000 m^2 Golf courses: 3000 m^2
(2)	Beauty and hair dressing services	Number of beauty and hair dressing services across the country x floor area per services	Number of beauty and hair dressing services in cold region x floor area per services	Number of beauty and hair dressing services in warm region x floor area per services	
(3)	Sport facilities	Number of sport facilities across the country x floor area per institution	Number of sport facilities in cold region x floor area per institution	Number of sport facilities in warm region x floor area per institution	
(4)	Golf courses	Number of golf courses across the country x floor area per course	Number of golf courses in cold region x floor area per course	Number of golf courses in warm region x floor area per course	

	Building segment		Region			Remarks
			Whole country	Cold region	Warm region	
(5)		Other than the above	(Total of H) – (total of H (1) to (4))	(Total of H in cold region) – (total of H (1) to (4) in cold region	(Total of H in warm region) – (total of H (1) to (4) in warm region	

The future total floor area for commercial use was assumed to gently expand till FY2030 and move sideways in and after FY2030 as shown in Fig. 2-37 in the light of Long-term Prospect of Supply and Demand of Energy, and was estimated by region and building segment in the future by applying this long-term change rate to each category (region and building segment) of current total floor area for commercial use shown in Table 2-15.

Table 2-17 shows the estimation result of future total floor area for commercial use by region and building segment.

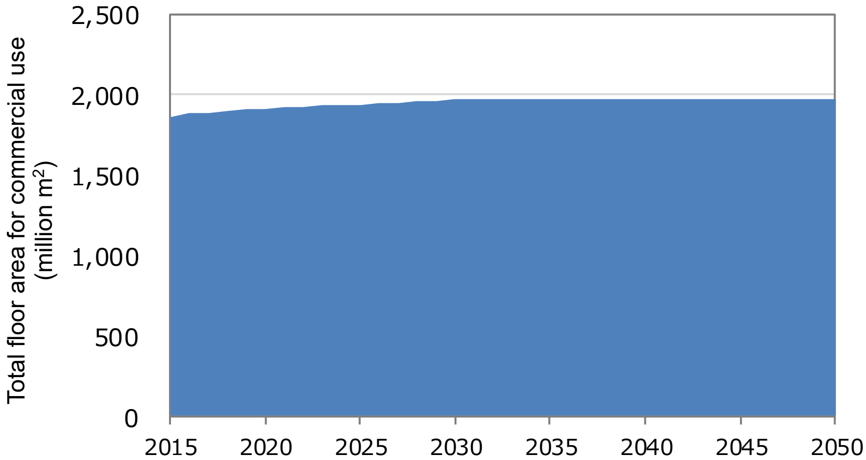


Fig. 2-37 Changes in future total floor area for commercial use

Table 2-17 Changes in future total floor area for commercial use by region and building segment

Building segment		Total floor area (million m^2) Cold region FY2020	Cold region FY2030	Cold region FY2040	Cold region FY2050	Warm region FY2020	Warm region FY2030	Warm region FY2040	Warm region FY2050
Offices	under 10,000 m^2	47	48	48	48	285	293	293	293
	10,000 m^2 or more	23	23	23	23	138	142	142	142
Stores	under 10,000 m^2	57	58	58	58	250	257	257	257
	10,000 m^2 or more	35	36	36	36	153	157	157	157
Restaurants and bars		10	11	11	11	11	58	60	60
Schools	Nursery schools	4	4	4	4	21	22	22	22
	Kindergartens	3	3	3	3	14	14	14	14
	Elementary, junior high, and senior high schools	46	48	48	48	184	189	189	189
	Universities	13	14	14	14	66	68	68	68
	Other schools	4	4	4	4	19	19	19	19
Hotels and inns		20	19	20	20	20	68	70	70
Hospitals		22	22	23	23	23	98	101	101
Others	Welfare institutions	11	11	11	11	50	51	51	51
	Beauty and hair dressing services	3	3	3	3	11	12	12	12
	Sport facilities	2	2	2	2	13	13	13	13
	Golf courses	1	2	2	2	7	7	7	7
	Other than the above	41	42	42	42	138	142	142	142

2) Hot water supply demand per floor area by region and building segment

The hot water supply demand per floor area by region and building segment was set as shown in Table 2-18 in the light of the assumptions in the Act on the Improvement of Energy Consumption Performance of Buildings (Building Energy Efficiency Act).

Specifically, the hot water supply demand consumption rate by region and by room application was set by "Standard Primary Energy Consumption Rate of Hot-Water Supply Equipment" shown as the calculation base of standard primary energy consumption, and at the same time, the standard area by room application of each building segment was assumed and calculated in the light of the specifications, etc. of model buildings used in the Model Building Method of Building Energy Efficiency Act. The hot water supply demand consumption rate was set by using the value of one region of energy-saving area classification for the cold region and those of five regions for the warm region.

Table 2-18 Water supply demand per floor area by region and building segment

Building segment		HP water heater introduction suitability	Hot water demand consumption rate (MJ/m^2-year)	
			Cold region	Warm region
Offices	under 10,000 m^2	△	13	11
	10,000 m^2 or more	○	12	10
Stores	under 10,000 m^2	△	105	90
	10,000 m^2 or more	○	61	51
Restaurants and bars		○	611	519
Schools	Nursery schools	○	86	73
	Kindergartens	△	32	27
	Elementary, junior high, and senior high schools	○	86	73
	Universities	○	178	150
	Other schools	△	86	73
Hotels and inns		○	210	178
Hospitals		○	312	265
Others	Welfare institutions	○	312	265
	Beauty and hair dressing services	○	502	502
	Sport facilities	○	1221	1221
	Golf courses	○	670	670
	Other than the above	△	5	5

<Method for setting the hot water supply demand: Case of offices under 10,000 m^2>

The hot water supply demand is calculated by weightedly averaging the hot-water supply demand consumption rate by room application using the area as shown below:

Model building specifications					Hot-water supply consumption rate by region and room application (MJ/m^2-year)	
Floor	Room name	Room application	Hot-water supply load targeted for calculation	Room area (m^2)	Cold region (energy-saving region category: 1 region)	Warm region (energy-saving region category: 5 regions)
1F	Dressing room 1	Dressing room or warehouse	■	9	663	563
1F	Dressing room 2	Dressing room or warehouse	■	9	663	563
1F	Office 1	Office	■	319	13	11
1F	Office 2	Office	■	135	13	11
2-5F	Office 1	Office	■	1080	13	11
2-5F	Office 2	Office	■	864	13	11
6F	Office 1	Office	■	270	13	11
6F	Office 2	Office	■	216	13	11
1F	Guard's room	Office	■	15	13	11
1F	Meeting room	Office	■	25	13	11
2-5F	Meeting room	Office	■	100	13	11
6F	Meeting room	Office	■	25	13	11
1F	Windbreak room	Corridor		8		
1F	Lobby	Corridor		24		
1F	Corridor	Corridor		56		
1F	---	Corridor		---		
2-5F	Corridor	Corridor		224		
2-5F	Elevator lobby	Corridor		50		
2-5F	---	Corridor		---		
6F	Lavatory 1	Lavatory		26		
6F	---	Lavatory		---		

Total	Weighted average by room area	
4,124	13	11

3) Hot-water supply demand of the commercial sector

Fig. 2-38 shows the estimation result of future hot-water supply demand of the business sector by market segment on the basis of the aforementioned assumption.

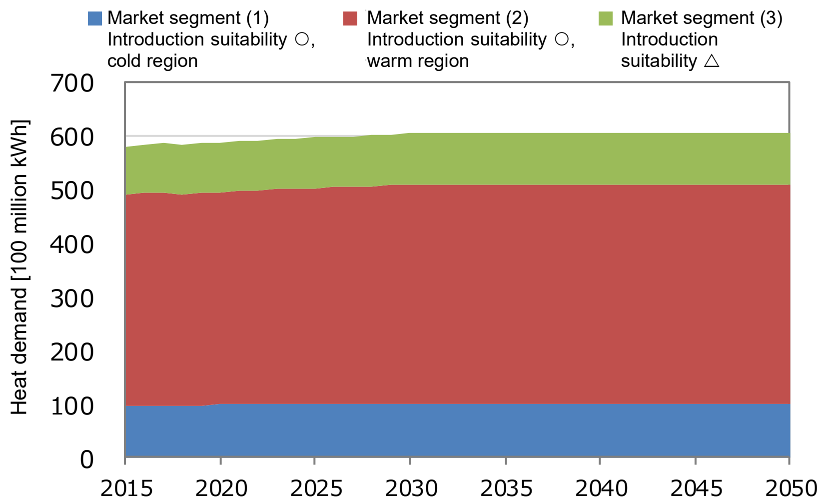


Fig. 2-38 Changes in hot water supply demand by market segments of commercial sector in the future

(2) Shares of hot water supply demand covered by commercial heat pump water heaters

The current share of hot water supply demand covered by commercial heat-pump water heaters was calculated by estimating the hot water supply demand covered by commercial heat-pump water heaters on the basis of actual delivery capacity and survival curve and the assumption of equivalent full-load hours of operation, and by dividing the estimated hot water demand by the hot water demand of the whole commercial sector shown in Paragraph 1).

The future shares of hot water supply demand which commercial heat pump water heaters would cover were set by applying the logistic regression to the current share changing conditions of heat demand to be covered by commercial heat-pump water heaters. To apply the logistic regression, three cases of high-rank, middle-rank, and low-rank were assumed for upper-limit asymptotic values of shares of commercial heat pump water heaters.

1) Current commercial water heater delivery capacity

Fig. 2-39 shows changes in current commercial water heater delivery capacity.

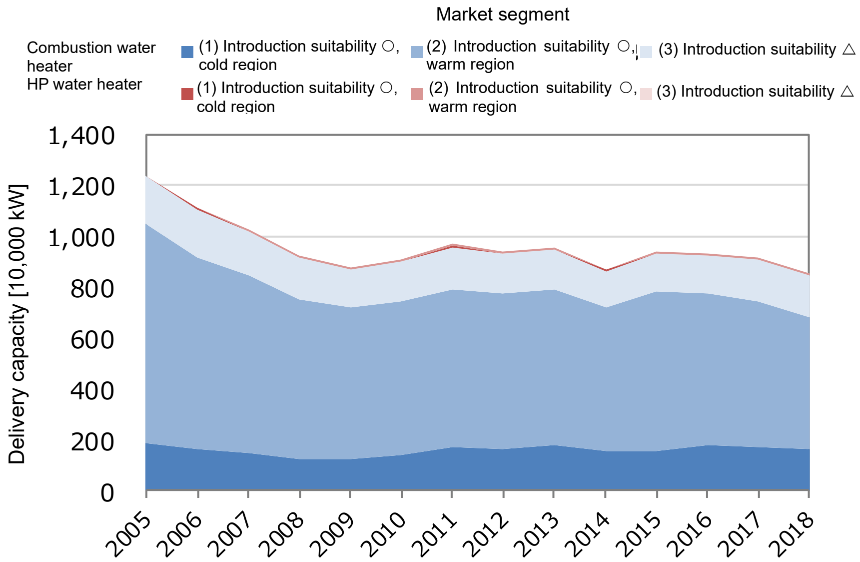


Fig. 2-39 Changes in current commercial water heater delivery capacity

The actual quantity shipped of heat-pump water heaters was set from the self-statistics of JRAIA as shown in Table 2-12 of 2.3.1(1). The actual quantity shipped of combustion water heaters was set from "Heater Almanac" issued by JHIA and the self-statistics of JGKA.

In the above-mentioned statistical data, the actual quantity shipped on the capacity base is shown for heat-pump water heaters but for combustion water heaters, the actual quantity shipped on the quantity base only is shown. Therefore, the average single-unit capacity was set as shown in Fig. 2-38 so that the estimated results of current (FY2018) hot water supply demand shown in Table 2-19 can secure consistency with the hot water supply demand to be estimated in consideration of the survival curve later discussed and equivalent full-load hours of operation.

Table 2-19 Assumed average single-unit capacity of combustion water heaters

Water heater	Market segment	Average single-unit capacity
Combustion water heater	(1) (Building segment: Introduction suitability of HP water heaters ○; Region: Cold region)	120 kW
	(2) (Building segment: Introduction suitability of HP water heaters ○; Region: Warm region)	314 kW
	(3) (Building segment: Introduction suitability of HP water heaters △)	22.4 kW

2) Average usage period and survival curve

The average usage period was set as shown in Table 2-20 in conformity to the assumption in the reports of METI's 2014 Projects for Promoting a Rational Use of Energy (Survey on energy-saving technologies in industrial furnaces, etc.).

Table 2-20 Assumed average usage period of commercial water heaters

Types of water heaters	Average usage period
Combustion water heaters for commercial use	14.6 years
HP water heaters for commercial use	12.9 years

The survival curve (survival rate by usage periods) is given by the following formula. Parameters α and β that express the shape of the survival curve must be set. In the present case, settings were performed in such a manner that the average usage period of commercial water heaters assumed from the survival curve conformed to the assumption of the above-mentioned average usage period.

$$\text{Survival rate} = e^{-\alpha(elapsed\ years^{\beta})}$$

Fig. 2-40 shows the survival curve set as described above.

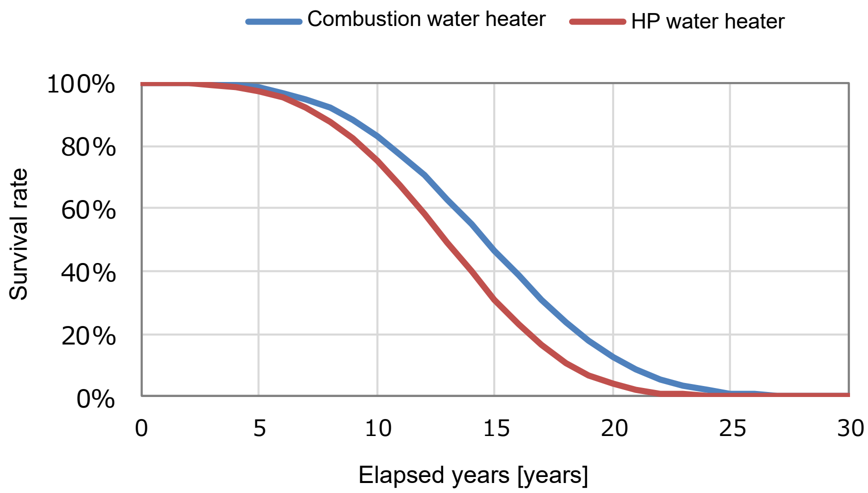


Fig. 2-40 Survival curve of commercial water heaters

3) Equivalent full load hours of operation for commercial water heaters

The equivalent full load hours of operation for commercial water heaters were set as shown in Table 2-21 in the conformity to the assumption in the reports of METI's 2014 Projects for Promoting a Rational Use of Energy (Survey on energy-saving technologies in industrial furnaces, etc.).

Table 2-21 Assumption of equivalent full load hours of operation for commercial water heaters

Heater types	Equivalent full load hours of operation
Combustion water heaters for commercial use	363 h/year
HP water heaters for commercial use	2,366 h/year

4) Current share of hot water supply demand covered by commercial heat pump water heaters

On the basis of the foregoing assumption, the hot water supply demand which each water heater covers was calculated and the current share of hot water supply demand covered by commercial heat pump water heaters was estimated, the results of which are shown in Fig. 2-41.

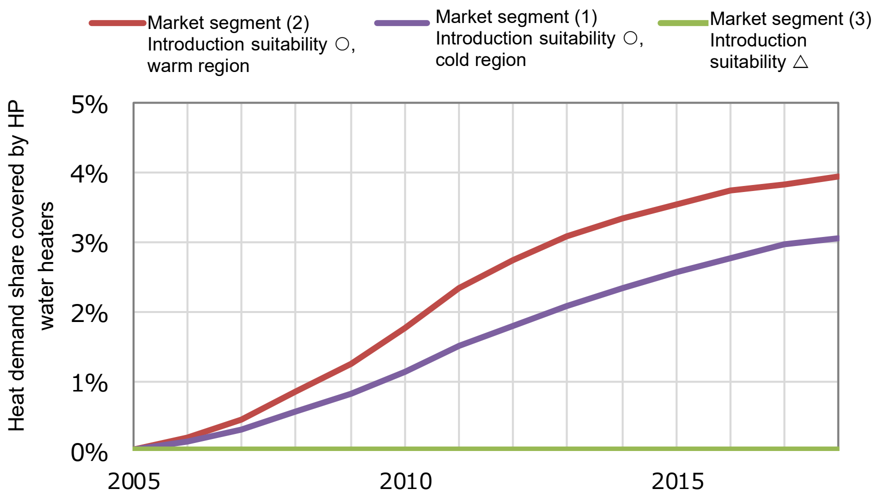


Fig. 2-41 Changes in current shares of hot water supply demand which commercial heat-pump water heaters cover

5) Upper introduction limit of commercial heat pump water heaters

The future shares of hot water supply demand which commercial heat pump water heaters would cover were estimated by applying the logistic curve to the current share changing conditions. To apply the logistic regression, as shown in Table 2-22, three cases of high-rank, middle-rank, and low-rank were assumed as upper-limit asymptotic values of shares of commercial heat pump water heaters.

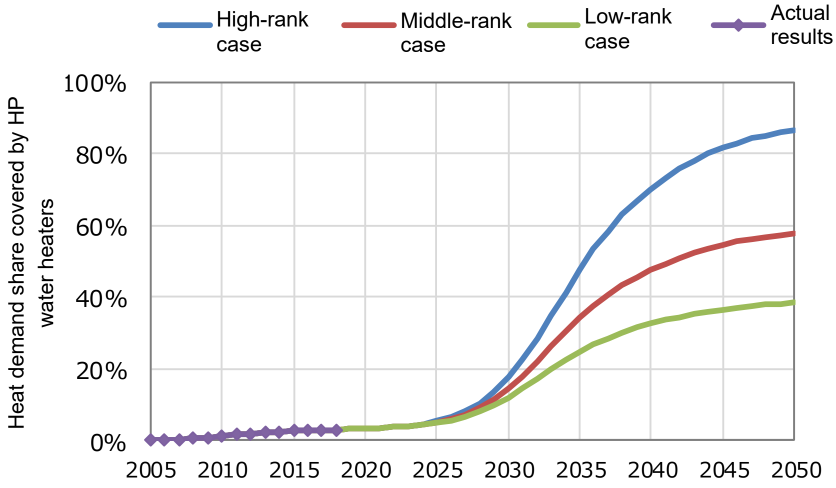
The shares of commercial heat pump water heaters were assumed to approach the upper-limit asymptotic values in about FY2065 when products go through just about 4 product life cycles.

Table 2-22 Assumption of upper introduction limit of commercial HP water heaters

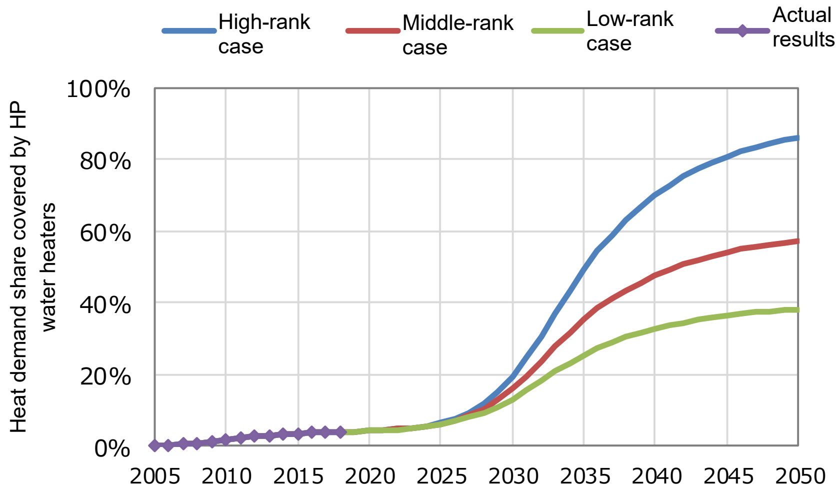
Case	Upper introduction limit of commercial HP water heaters (upper limit of share of hot water supply demand to cover)
High-rank	Hot water demand of each market segment x 90%
Middle-rank	Hot water demand of each market segment x 60%
Low-rank	Hot water demand of each market segment x 40%

On the basis of the foregoing assumption, future shares of heat demand which commercial heat pump water heaters would cover were estimated for the high-rank case, middle-rank case, and low-rank case, respectively, the results of which are shown in Fig. 2-42.

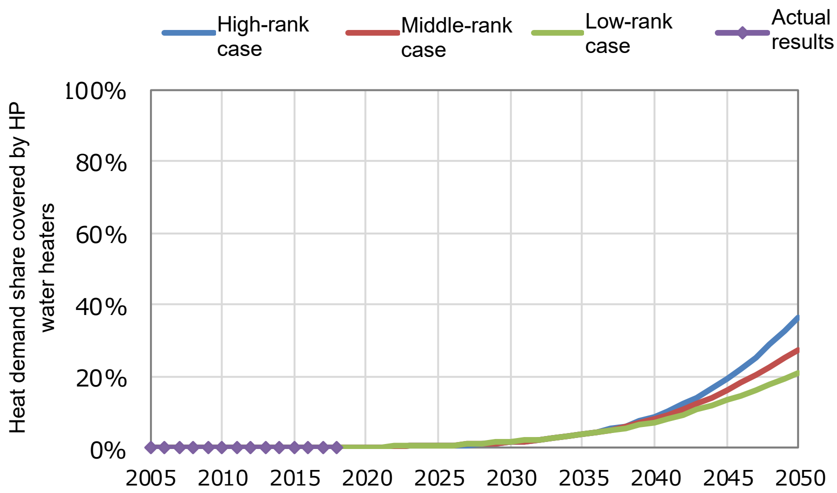
For Market segment (3) (Building segment: Introduction suitability of HP water heaters △), diffusion of heat pump water heaters which are expected to respond to local hot water demand (commercialization is anticipated sometime in the future) was assumed to be started in FY2025 as described above. The diffusion speed was estimated by assuming that it was same as Market segment (2) (Building segment: Introduction suitability of HP water heaters ○; Region: Warm region).



Market segment (1) (Building segment: Introduction suitability of HP water heaters ○; Region: Cold region)



Market segment (2) (Building segment: Introduction suitability of HP water heaters ○; Region: Warm region)



Market segment (3) (Building segment: Introduction suitability of HP water heaters △)

Fig. 2-42 Assumption of share of heat demand to be covered by future commercial HP water heaters

(3) Flow efficiency of commercial water heaters

The flow efficiency of commercial water heaters by equipment type was defined as shown in Fig. 2-43.

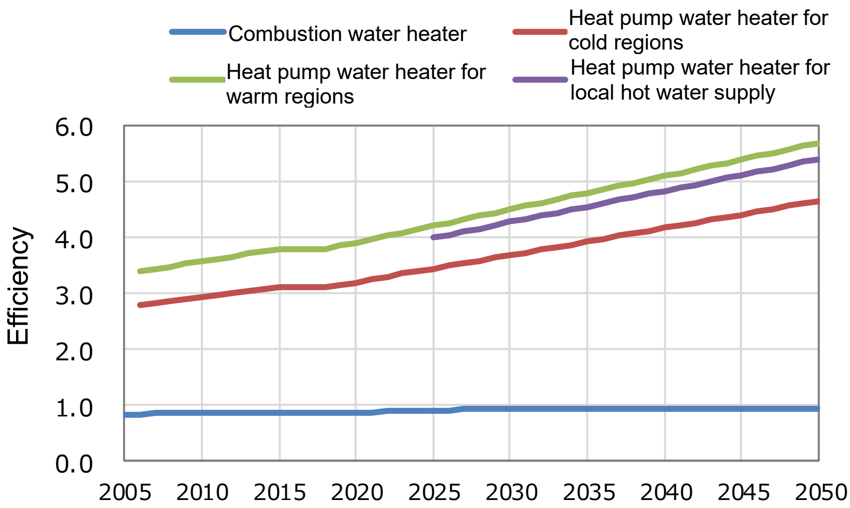


Fig. 2-43 Presumed flow efficiency of commercial water heaters by equipment type

The current efficiency of heat pump water heaters for warm regions was defined according to HPTCJ studies based on the efficiency of heat pump water heaters currently on the market. Going forward, efficiency is presumed to reach 1.5 times current (FY2018) levels by 2050. Intervening years were filled in by linear interpolation.

The efficiency of heat pump water heaters for cold regions is presumed to be 0.82 times (2.7 ÷ 3.3) that of heat pump water heaters for warm regions based on the ratio of efficiency standard values for household heat pump water heaters for general regions and cold regions under the current Top Runner Program (Hot water storage capacity: 320 to 550 L; With heat retention function; Number of hot water storage cans: Presumed efficiency standard value for one can is 3.3 for general regions, and 2.7 for cold regions).

As mentioned above, widespread take-up of heat pump water heaters for local hot water supply is presumed to begin in FY2025 and the efficiency then is presumed to be 4.0. Future projections have been set based on the presumption that the efficiency of heat pump water heaters for both warm and cold regions will continue to improve at roughly the same rate.

The efficiency of combustion water heaters was defined in the same manner as in the METI report “2014 infrastructure development project for advancing the streamlining of energy use (survey on energy-saving technology in industrial furnaces and such),” that is, by presuming an efficiency of 0.85 for combustion types and 0.95 for latent heat recovery combustion types, and weighting the average by their shipment ratio. The current shipment ratio of combustion type and latent heat recovery combustion type units were defined based on the number of units shipped of both of these types as outlined in the “Heating Equipment Year Book” issued by the Japan Heating Industrial

Association, and in independent statistics published by the Japan Industrial Association of Gas and Kerosene Appliances. Going forward, similar to the values defined for gas water heaters and oil water heaters for household use, it is presumed that the ratio of latent heat recovery combustion type units will reach 100% by 2030. Intervening years were filled in by linear interpolation.

2.3.4 Calculation results

(1) Capacity shipped and capacity in stock

Fig. 2-44 and Fig. 2-45 show estimations of the capacity of commercial heat pump water heaters shipped and in stock based on the above presumptions.

The capacities of commercial heat pump water heaters both shipped and in stock are expected to grow significantly, with capacities shipped and in stock for the FY2050 cross-section reaching roughly 1.1 million kW and 13.4 million kW, respectively. Furthermore, growth is expected to continue after FY2050, albeit at a slower rate.

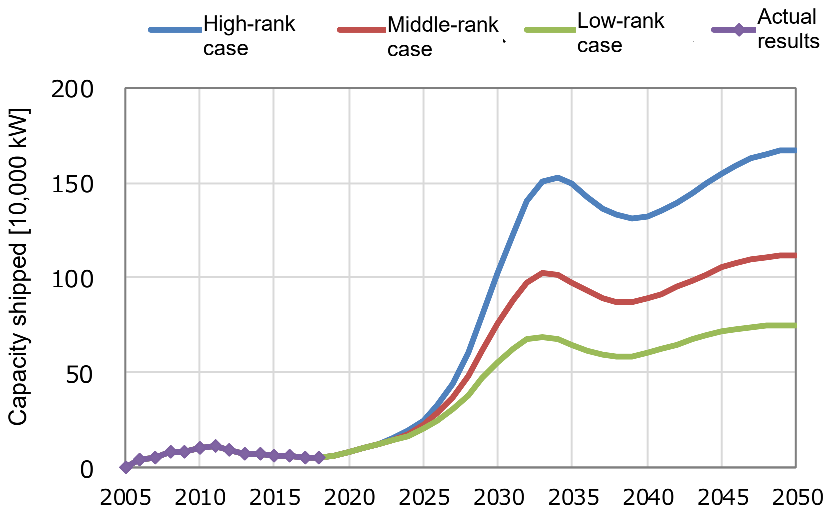


Fig. 2-44 Estimated capacity of commercial heat pump water heaters shipped

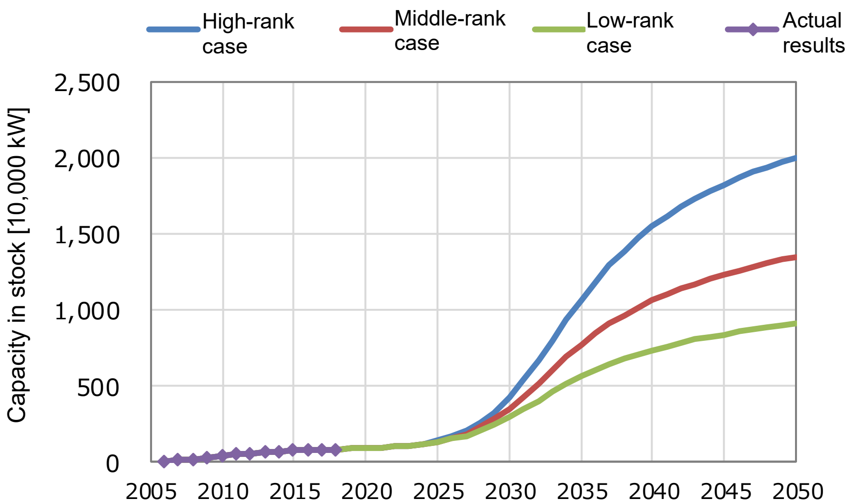
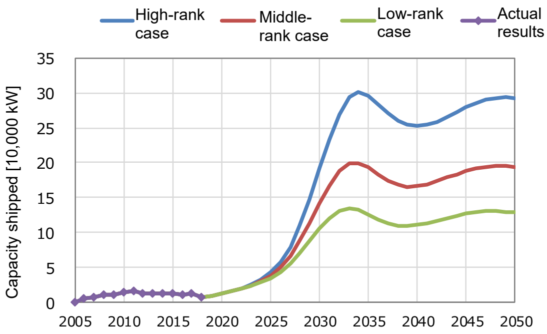


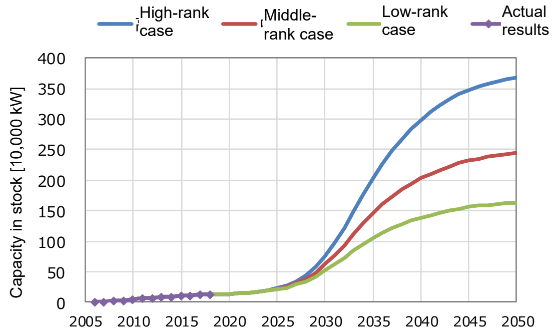
Fig. 2-45 Estimated capacity of commercial heat pump water heaters in stock

(Reference) Capacity shipped and in stock by market segment

For reference purposes, Fig. 2-46 shows estimations of the capacity of heat pump water heaters shipped and in stock by market segment for high-order, middle-order, and low-order scenarios.

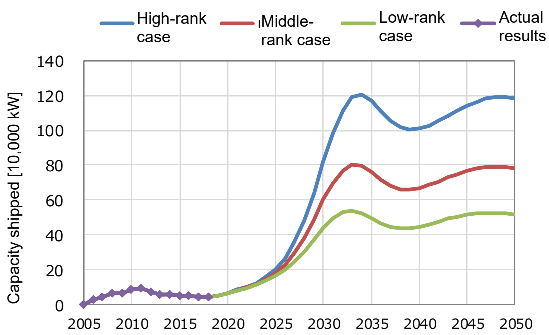


Capacity shipped

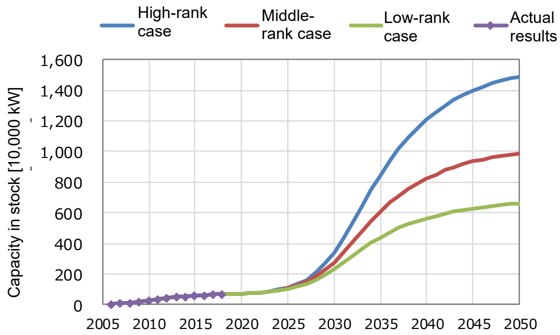


Capacity in stock

Market segment [1] (Building segment - Suitability for introducing heat pump water heaters: Good, Region: Cold)

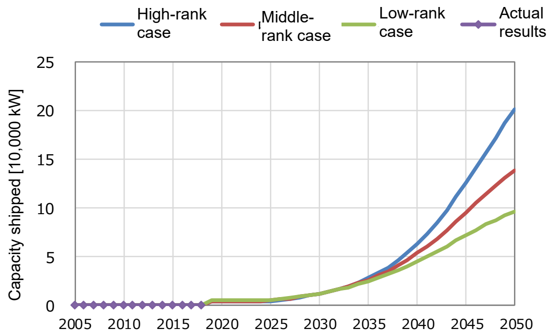


Capacity shipped

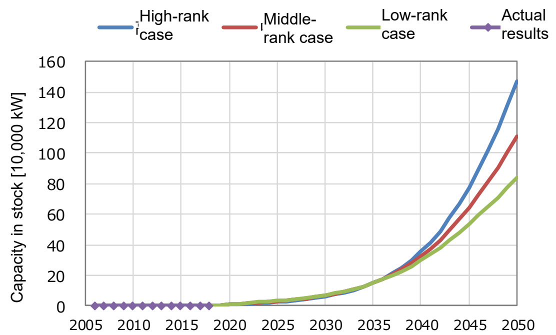


Capacity in stock

Market segment [2] (Building segment - Suitability for introducing heat pump water heaters: Good, Region: Warm)



Capacity shipped



Capacity in stock

Market segment [3] (Building segment - Suitability for introducing HP water heaters: Average)

Fig. 2-46 Estimated capacity of commercial heat pump water heaters shipped and in stock by market segment.

(2) Primary energy consumption, energy-saving effect, CO_2 reduction effect

Fig. 2-47 shows results of calculations of primary energy consumption made based on the above estimations of capacity shipped and in stock, flow efficiency shown in (3), operating time under full load equivalent, and electric power to primary energy conversion coefficient.

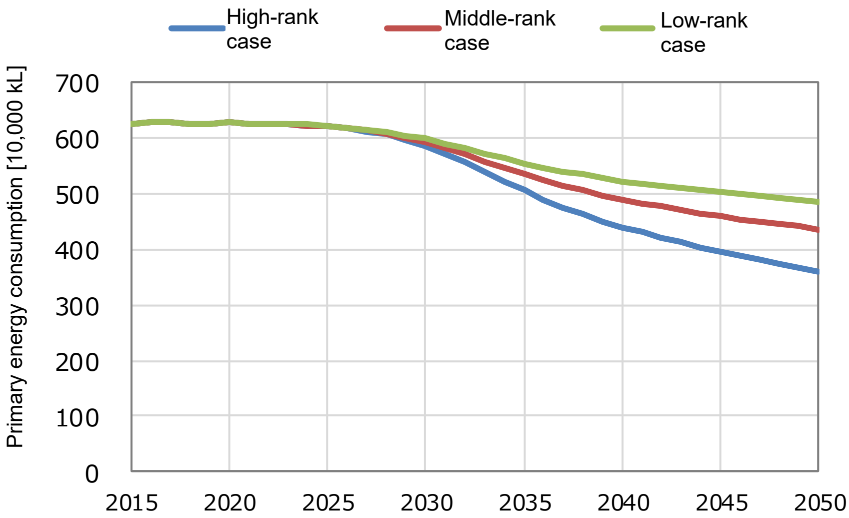


Fig. 2-47 Estimated primary energy consumption: Commercial heat pump water heater

In addition, based on the above results, Fig. 248 and Table 223 show the energy-saving effects for each scenario above current fixed scenarios (primary energy consumption reduction effect), presuming that the current (FY2018) share of commercial heat pump water heaters in stock and their flow efficiency remains constant going forward.

The amount of energy saved in the medium-order scenario for the FY2050 cross-section is estimated to be 1.48 million kL/year, with the combustion water heater substitution effect making up 860,000 kL/year, and the effect of efficiency improvements made to heat pump water heaters making up 620,000 kL/year.

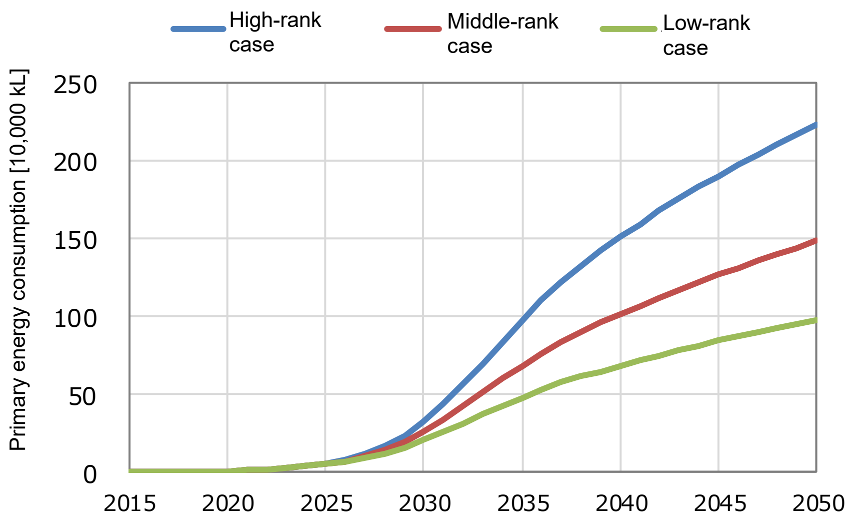


Fig. 2-48 Estimated energy-saving effects: Commercial heat pump water heaters

Table 2-23 Breakdown of energy-saving effects: Commercial heat pump water heaters

Scenario	Breakdown		Energy-saving effect (10,000 kL/year)			
			FY2020	FY2030	FY2040	FY2050
High-order scenario	Total		1	33	151	224
		Combustion water heater substitution effect	1	24	100	131
		Effects of heat pump water heater efficiency improvements	0	8	52	93
Medium-order scenario	Total		1	26	102	148
		Combustion water heater substitution effect	1	19	67	86
		Effects of heat pump water heater efficiency improvements	0	7	35	62
Low-order scenario	Total		1	20	68	98
		Combustion water heater substitution effect	1	15	45	56
		Effects of heat pump water heater efficiency improvements	0	5	24	42

Note) The sum of values and the displayed totals do not always agree as numbers have been rounded.

Fig. 2-49 and Table 2-24 show estimations of the CO2 reduction effect which is obtained by multiplying the above energy-saving effect by the CO2 primary unit. As for different fuels used in combustion water heaters, the FY2018 fuel consumption for hot water supply provided in the Energy & Economic Statistics Handbook was referenced, the emission coefficient was calculated using the weighted averages of city gas and fuel oil A, and this was presumed to remain constant.

The CO2 reduction effect in the medium-order scenario for the FY2050 cross-section is estimated to be 6.01 million t-CO2/year, with the combustion water heater substitution effect making up 5.71 million t-CO2/year, and the effect of efficiency improvements made to heat pump water heaters making up 300,000 t-CO2/year.

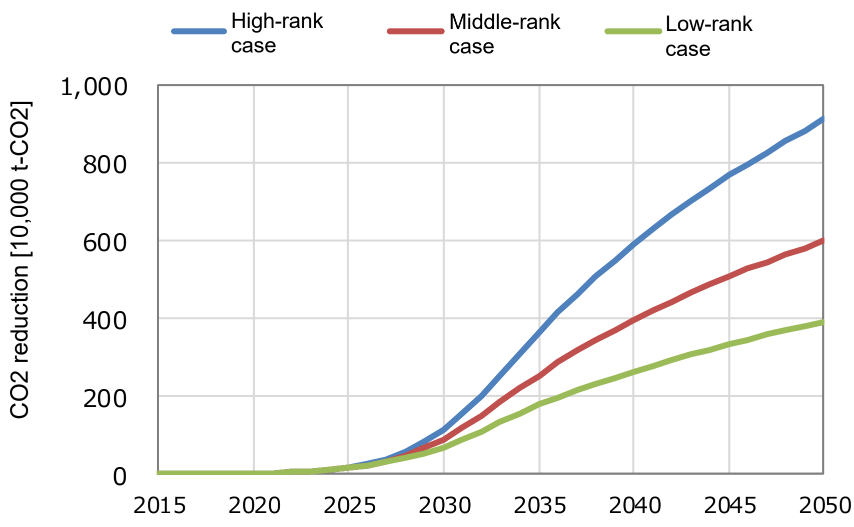


Fig. 2-49 Estimated CO2 reduction effects: Commercial heat pump water heaters

Table 2-24 Breakdown of CO2 reduction effects: Commercial heat pump water heaters

Scenario	Breakdown		CO2 reduction effect (10,000 t-CO2/year)			
			FY2020	FY2030	FY2040	FY2050
High-order scenario	Total		2	113	593	912
		Combustion water heater substitution effect	2	100	543	868
		Effects of heat pump water heater efficiency improvements	0	12	50	44
Medium-order scenario	Total		2	88	397	601
		Combustion water heater substitution effect	2	79	363	571
		Effects of heat pump water heater efficiency improvements	0	10	34	30
Low-order scenario	Total		2	69	265	393
		Combustion water heater substitution effect	2	62	242	373
		Effects of heat pump water heater efficiency improvements	0	8	23	20

Note) The sum of values and the displayed totals do not always agree as numbers have been rounded.

2.4 Commercial air conditioning

2.4.1 Preconditions

Central and individual air conditioning are examined separately in our examination of commercial air conditioning.

As for central air conditioning, the effects of substituting absorption refrigeration units with chilling units or turbo refrigeration units are evaluated. For individual air conditioning, the effects of improvements being made to the efficiency of packaged air conditioners are evaluated. (No substitution is presumed for gas heat pump [GHP] air conditioning.)

As for turbo refrigeration units and absorption refrigeration units, the "for air conditioning" classification in the individual statistics from the Japan Refrigeration and Air-Conditioning Industry Association is presumed to refer to commercial air conditioning. As for chilling units, commercial air conditioning is presumed to refer to those not counted among the 5% of units with 30 horsepower or more (The 5% of units with 30 horsepower or more were presumed to be industrial air-conditioning units). As for packaged air conditioners (PAC), the “air conditioners for stores” and “multi-split type air conditioners for buildings” classifications in the individual statistics from the Japan Refrigeration and Air-Conditioning Industry Association were presumed to refer to commercial air conditioning.

Table 2-25 Commercial air conditioners evaluated

Type	Analyzed equipment	Statistical or documented equipment	
		Statistics	Equipment evaluated
Central	Commercial heat pump air conditioning	Japan Refrigeration and Air-Conditioning Industry Association Independent statistics	Turbo refrigeration units for air conditioning
			Chilling units smaller than the 5% of units with 30 horsepower or more
	Absorption refrigeration units	Japan Refrigeration and Air-Conditioning Industry Association Independent statistics	Absorption refrigeration units for air conditioning
Individual	Packaged Air conditioner	Japan Refrigeration and Air-Conditioning Industry Association Independent statistics	Air conditioners for stores, and multi-split type air conditioners for buildings

2.4.2 Flow of calculations

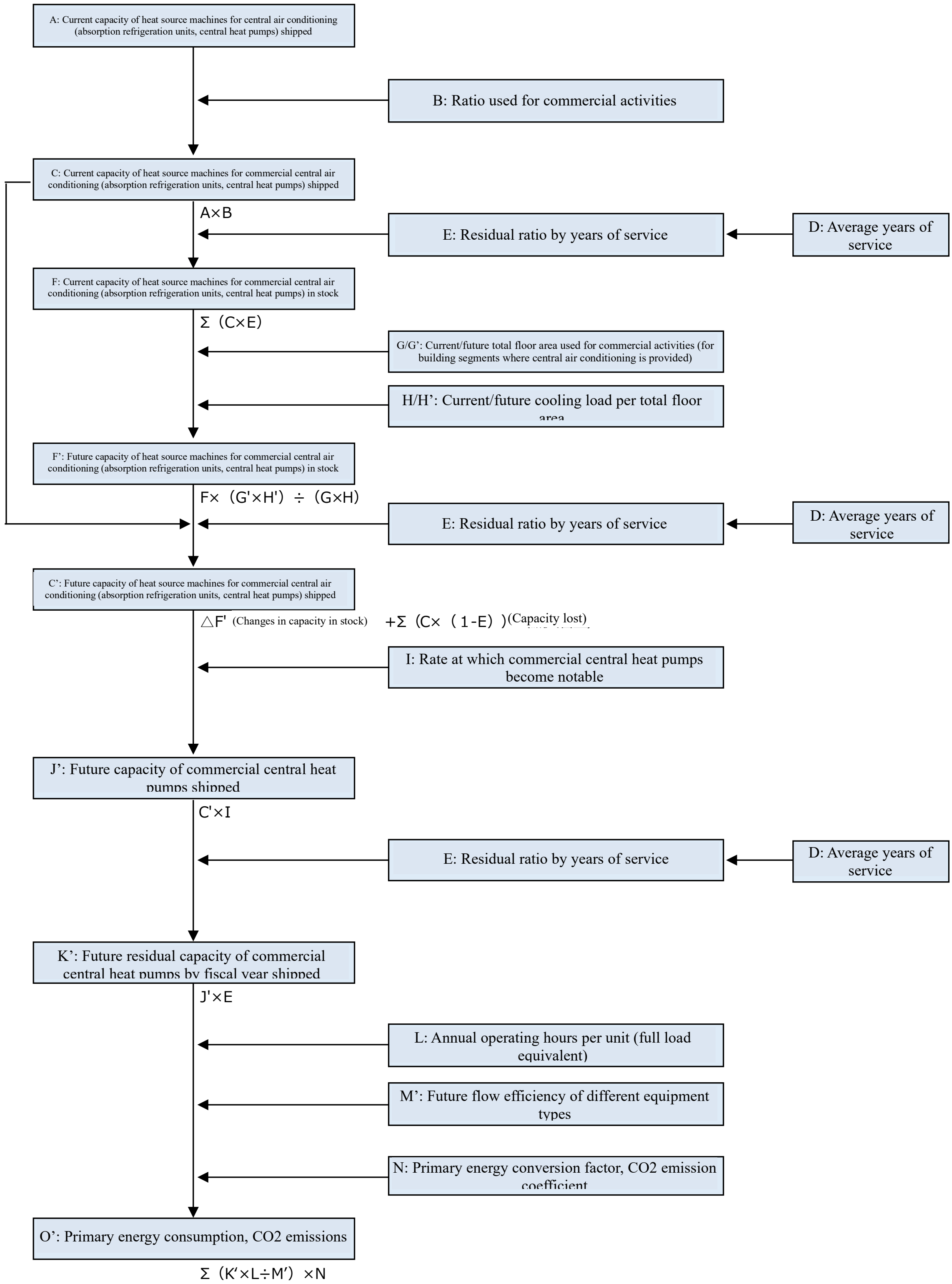


Fig. 2-50 Flow for calculating the outlook for widespread take-up of commercial air conditioners (central)

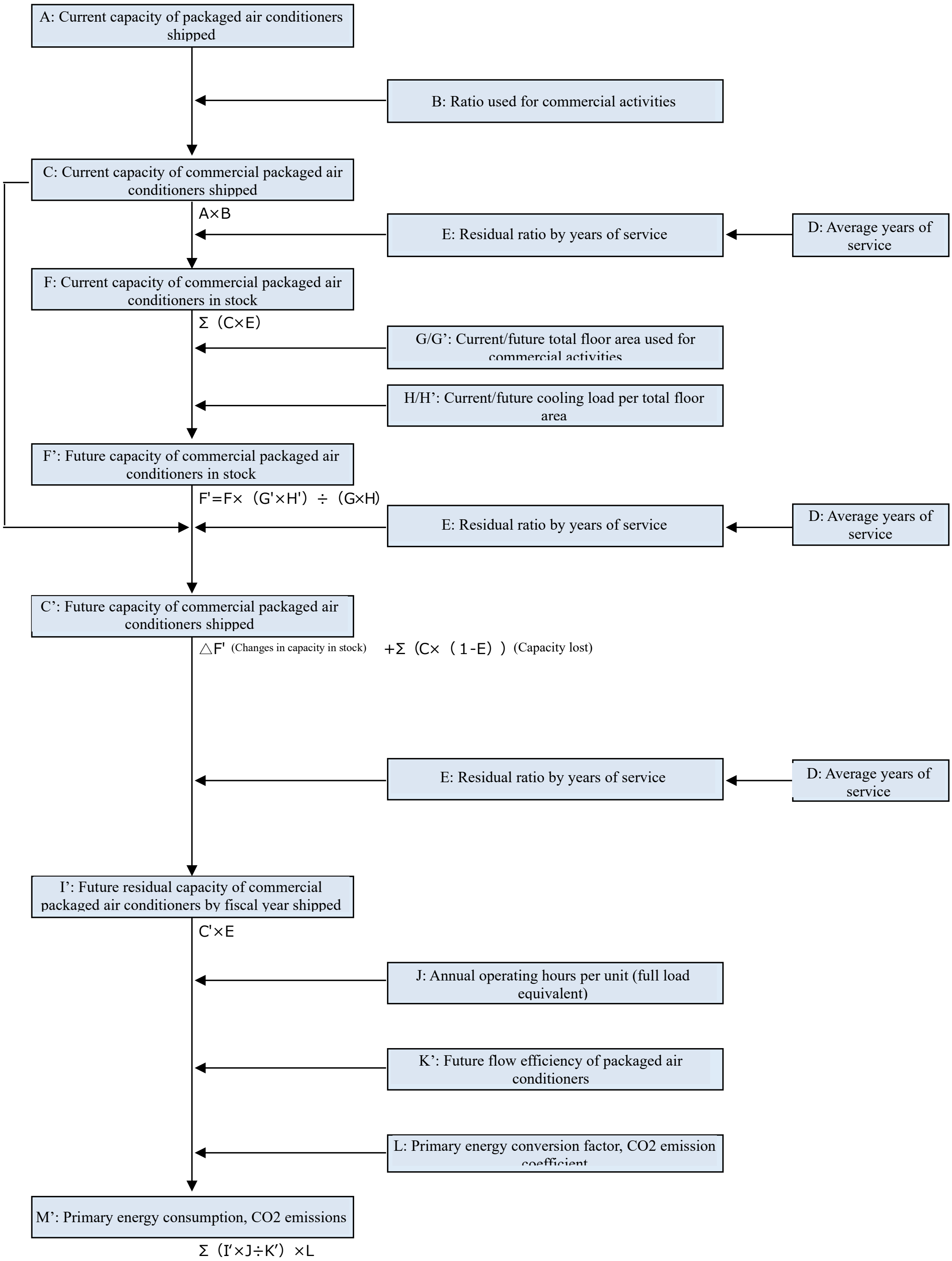


Fig. 2-51 Flow for calculating the outlook for widespread take-up of commercial air conditioners (individual)

2.4.3 Data used for calculation

(1) Market size for commercial air conditioners

1) Capacity of commercial air conditioners shipped

Fig. 2-52 shows the changes in the capacities of different commercial air conditioners shipped. A review of capacity shipped by equipment type shows that packaged air conditioners (individual air conditioners) make up the majority share at roughly 70-80% of the total. A breakdown of central air conditioning shows that absorption refrigeration units made up a large share until the early 2000s, with chilling units growing their share in recent years.

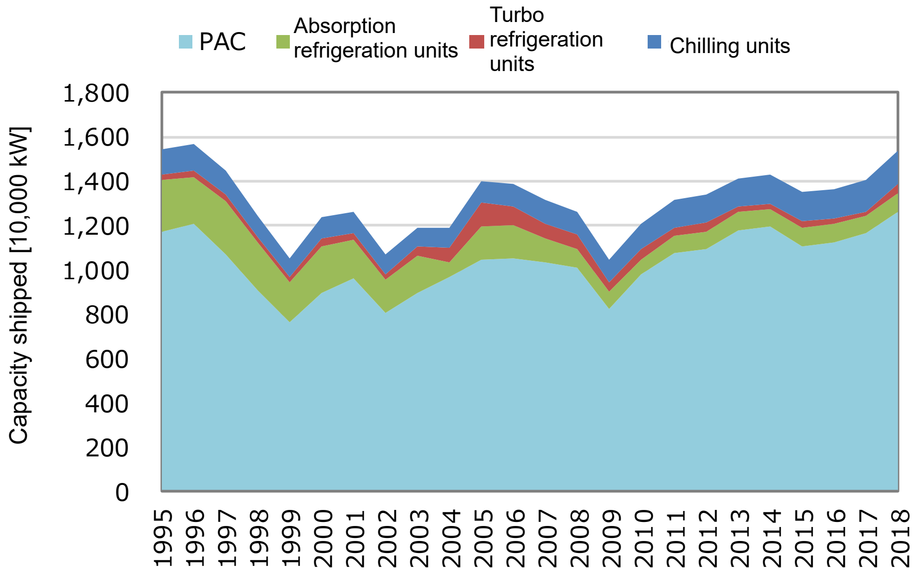


Fig. 2-52 Changes in the capacities of commercial air conditioners shipped (excluding GHP)

2) Average years of service, residual curve

The average years of service of different air conditioners have been defined as shown in Table 2-26, based on presumptions stated in the long-term energy supply and demand outlook.

Table 2-26 Presumed average years of service of commercial air conditioners

Type of equipment	Average years of service
Chilling units	15 years
Turbo refrigeration units	20 years
Absorption refrigeration units	17 years
Packaged air conditioners	15 years

Residual curves (residual ratio by years of service) are expressed using the following formula. Parameters α and β that represent the shape of the residual curve must be defined. Here, these were defined so that the average years of service of commercial air conditioners estimated from the residual curve is consistent with the average years of service presumed in the description above.

$$Residual\ ratio = e^{-\alpha(\text{Years elapsed}^{\beta})}$$

The defined residual curves are shown in Fig. 2-53.

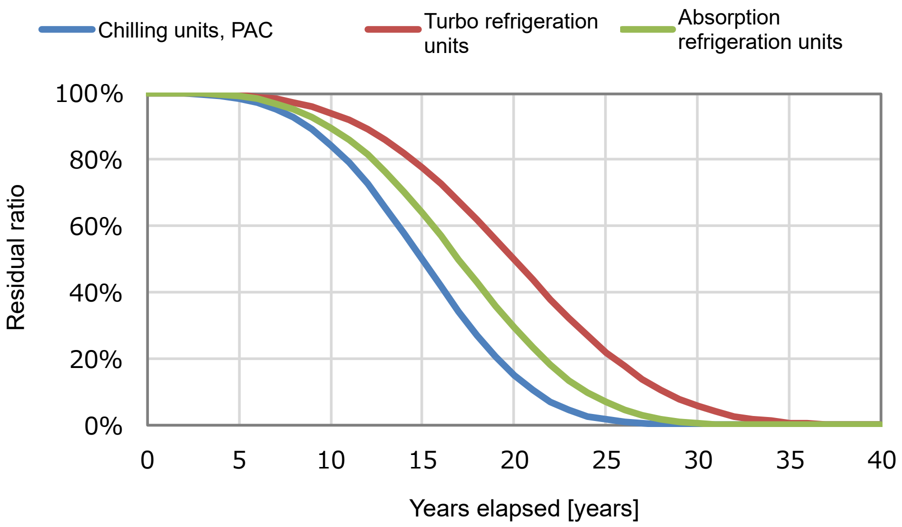


Fig. 2-53 Residual curves of commercial air conditioners

3) Market size for commercial air conditioners (capacity in stock)

The residual capacity for each year is estimated by multiplying the above-mentioned annual capacity shipped by the residual ratio, and the cumulative result is regarded as the current capacity of commercial air conditioners in stock.

Factors taken into account in estimating the future capacity of commercial air conditioning in stock include the growth in floor area for commercial use spurred by economic growth, and decline in heating/cooling loads per floor area resulting from the enforcement of the Building Energy Conservation Act. Fig. 254 shows the changes in floor areas for commercial use presumed by referencing the long-term energy supply and demand outlook, and the presumed decline in heating/cooling load per floor area based on the projected rise in the percentage of buildings that meet energy-saving standards and the ZEB standard.

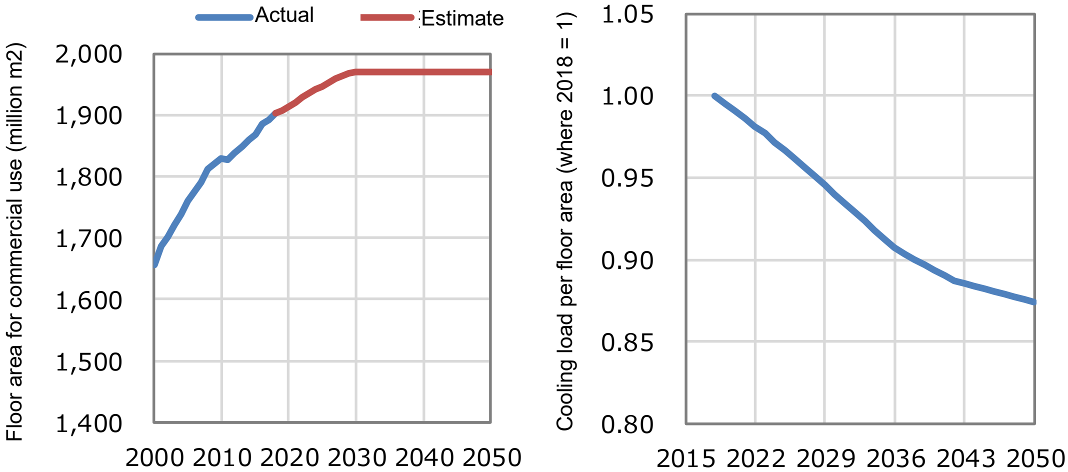


Fig. 2-54 Changes in floor area for commercial use and heating/cooling load per floor area

Fig. 2-55 shows the estimated future capacity of commercial air conditioning in stock based on the above. It is presumed that the ratio of central and individual (packaged) air conditioners will remain unchanged in the future.

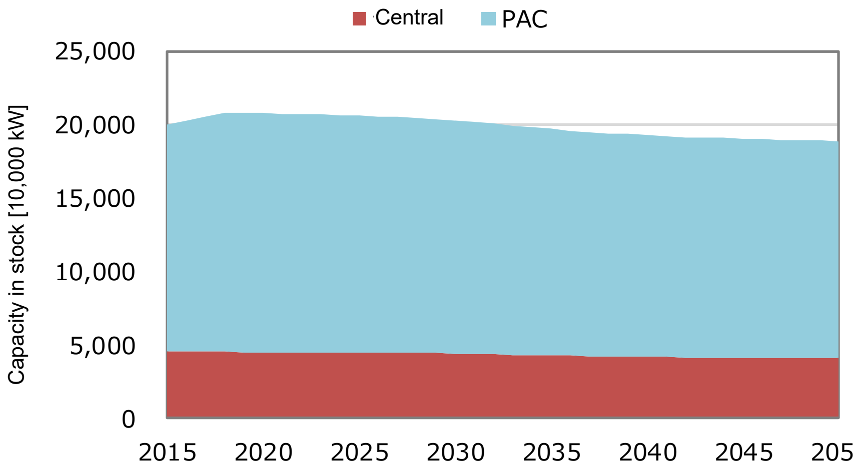


Fig. 2-55 Future capacity of commercial air conditioning in stock (excluding GHP)

(2) Specifications of commercial air conditioners

1) Flow efficiency of commercial air conditioners

The current flow efficiency of commercial air conditioners was defined according to an HPTCJ survey and based on the efficiency of equipment currently on the market. Going forward, it is presumed that by FY2050, APF will reach 5.7 for chilling units, and 8.0 for turbo refrigeration units (which are both currently at roughly 1.4). Intervening years were filled in by linear interpolation. For packaged air conditioners, three scenarios were defined depending on the degree of efficiency improvements, with a medium-order scenario presuming an AFP of 6.5 for FY2050 (roughly 1.4 times that of current), and high-order and low-order scenarios with FY2030 efficiencies that diverge by +5% and -5%, respectively. The FY2050 APF for absorption refrigeration units was defined by referencing the long-term energy supply and demand outlook for their APF in FY2030, and then extrapolating the rate of improvement leading up to FY2030.

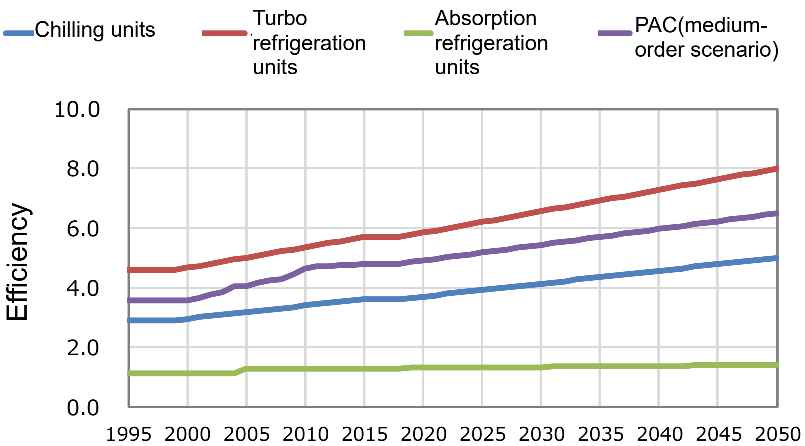


Fig. 2-56 Presumed flow efficiency of commercial air conditioners by equipment type

Table 2-27 Presumed efficiency of commercial heat pump air conditioning (individual)

Scenario	Efficiency of commercial heat pump air conditioning (individual)
High-order scenario	+5% relative to medium-order scenario in FY2030
Medium-order scenario	APF to improve to 6.5 in FY2050.
Low-order scenario	-5% relative to medium-order scenario in FY2030

2) Full load equivalent operating time

The full load equivalent operating time of commercial air-conditioners is presumed to be 1,200 h/year based on the "Operation Manual for Tool for Diagnosing the Effects of Energy-Saving Repairs" prepared by the Tokyo Metropolitan Government.

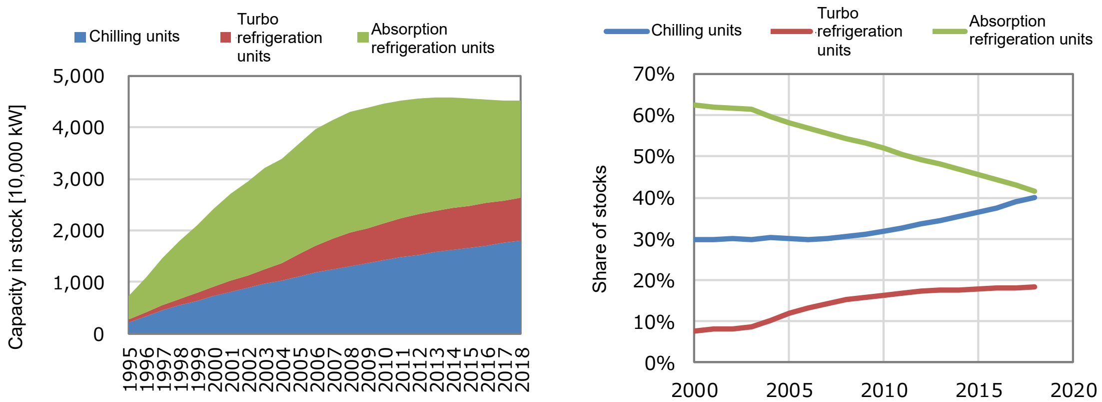
Table 2-28 Full load equivalent operating times in commercial sectors by industry

Benchmark categories		Average primary unit [kg-CO_2/m^2]	Full load equivalent operating time [h/year]				
			Heat source machine, cooling	Heat source machine, heating	Heat source machine, conveyance cooling	Heat source machine, conveyance heating	Air conditioners
Offices	(areas exclusively for tenants)	81.3	800	400	2,100	450	2,850
	Company-owned buildings	65.4					
Retail stores	(Convenience stores)	585.4	900	400	2,200	550	2,844
	(Drug stores)	295.4					
	(General supermarkets/department stores)	259.7					
	(Perishable foods, etc.)	387					
	(Food product manufacture and retail)	765.3					
	(Clothing)	124.8					
	(Automobile [new] retail)	63.4					
Eateries	(Japanese and western restaurants)	596.6	1,000	500	2,300	750	3,861
	(Izakaya/bars)	365.1					
	(Hamburger restaurants)	733.4					
	(Tea and coffee)	414.1					
	(Grilled meat)	561.9					
	(Chinese food/ramen)	985.1					
	(Other)	718.7					
Other	(Ryokan/Hotels)	125.2	1,000	1,200	3,000	5,000	5,110
	(Schools/educational facilities)	23.4	400	500	1,350	550	2,000
	(Nursery schools)	57.1					
	(Hospitals/Clinics)	106	1,000	900	3,400	1,600	5,110
	(Healthcare/care facilities)	72.6					
	(Fitness facilities)	203.5	1,000	500	2,300	1,100	3,861
	(Pachinko stores)	287.1					
	(Karaoke box stores)	252.1					
	(Game arcades)	333.9					
	(Libraries)	64.3					
	(Museums/art museums)	69.3					
	(Municipal government offices, etc.)	54.6	800	400	2,100	450	2,850
Other than benchmark categories			800	400	2,100	450	2,850

Source) "Operation Manual for Tool for Diagnosing the Effects of Energy-Saving Repairs," Tokyo Metropolitan Government

(3) Share of commercial heat pump air conditioners (chilling units, turbo refrigeration units) in stock

Shown below are estimations of the stock of chilling units, turbo refrigeration units, and absorption refrigeration units made by integrating records of actual adoption since FY1994 obtained from statistical data. Since the mid-2000s, the share of absorption refrigeration units has declined, and the shares of chilling units and turbo refrigeration units have increased. The share of chilling units has been on a rising increasing trend since 2010. As of FY2018, chilling units and turbo refrigeration units account for a combined share of roughly 58%.



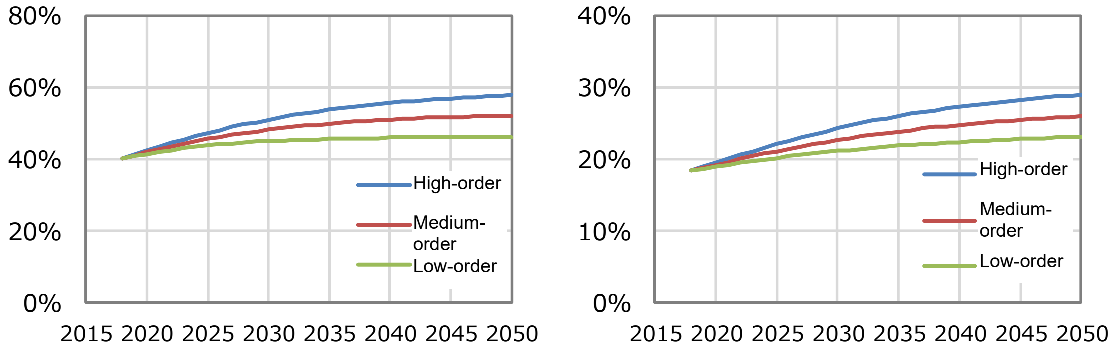
(Left: Capacity in stock, Right: Share of stocks)

Fig. 2-57 Status of adoption of commercial air conditioning (central)

The future share of chilling units and turbo refrigeration units in stock were estimated by applying a logistic curve to changes in the share of each of these types of units since FY2009. In applying logistic regression, as shown in Table 2-29, three scenarios—high-order, medium-order, and low-order scenarios—were presumed as upper asymptotic value limits of the share of heat pumps. The share of chilling units and turbo refrigeration units were presumed to remain largely unchanged from current levels. Furthermore, it was presumed that the upper asymptotic value limit will be approached at around FY2050, i.e, in roughly three product life cycles.

Table 2-29 Presumed upper limit of commercial heat pump air conditioning (central) adoption

Scenario	Upper limit of commercial heat pump air conditioning (central) adoption
High-order scenario	Capacity in stock × 90%
Medium-order scenario	Capacity in stock × 80%
Low-order scenario	Capacity in stock × 70%



(Left: Chilling units, Right: Turbo refrigeration units)

Fig. 2-58 Presumed share of commercial air conditioners (central) in stock

2.4.4 Calculation results

(1) Central

1) Capacity shipped and capacity in stock

Fig. 2-59-Fig. 2-62 show estimations of the capacity of chilling units and turbo refrigeration units shipped and in stock based on the above presumptions.

For the FY2050 cross-section in the medium-order scenario, the capacity of chilling units shipped and in stock will reach 1.37 million kW and 21.31 million kW, respectively, and the capacity of turbo refrigeration units shipped and in stock will reach 540,000 kW and 10.6 million kW, respectively.

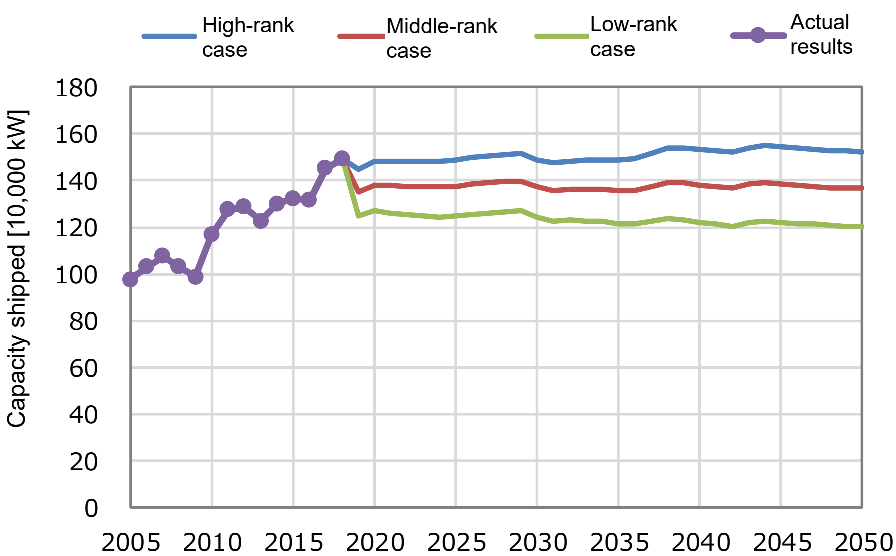


Fig. 2-59 Estimated capacity of commercial chilling units shipped

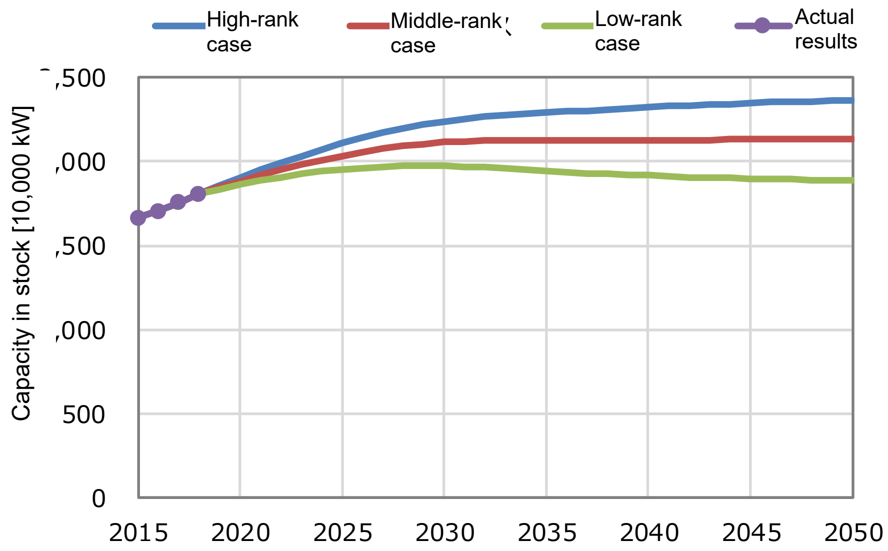


Fig. 2-60 Estimated capacity of commercial chilling units in stock

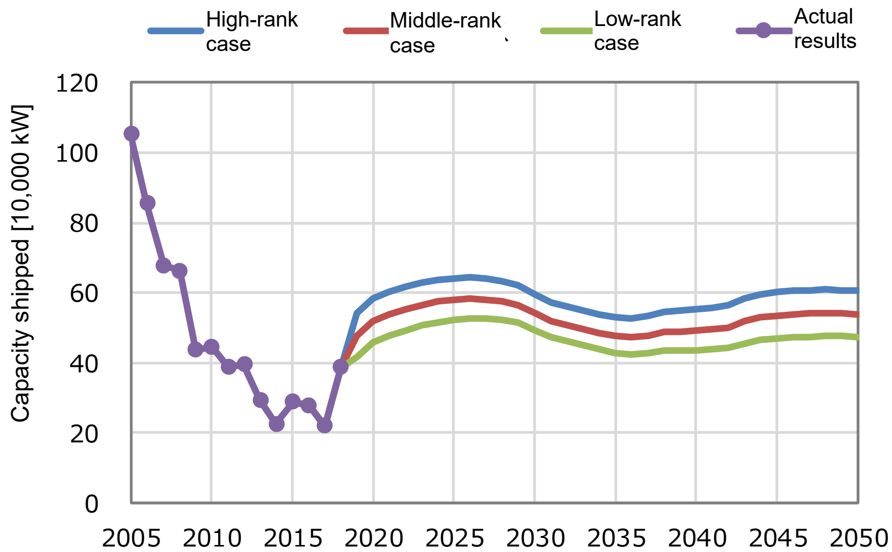


Fig. 2-61 Estimated capacity of commercial turbo refrigeration units shipped

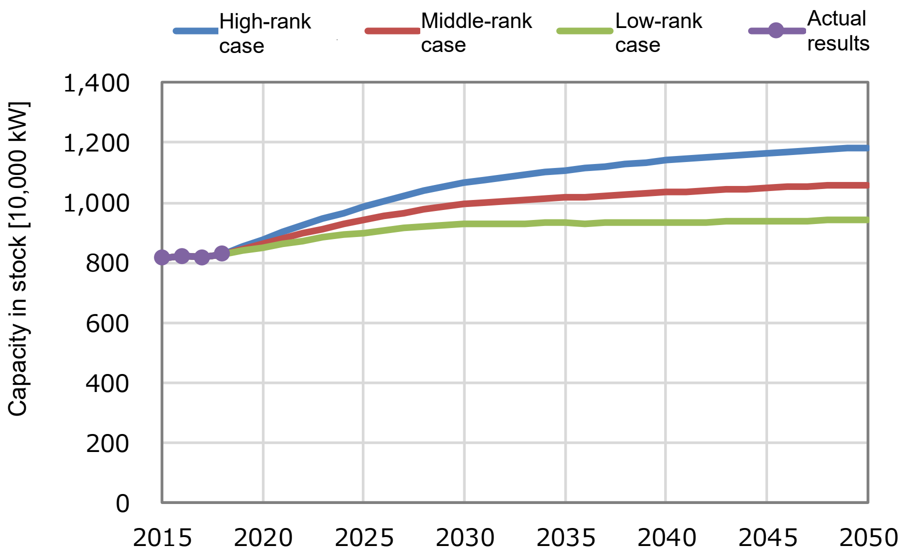


Fig. 2-62 Estimated capacity of commercial turbo refrigeration units in stock

2) Primary energy consumption, energy-saving effect, CO2 reduction effect

Fig. 2-63 shows results of calculations of primary energy consumption made based on the above estimations of capacity shipped and in stock, presumed flow efficiency, operating time under full load equivalent, and electric power to primary energy conversion coefficient.

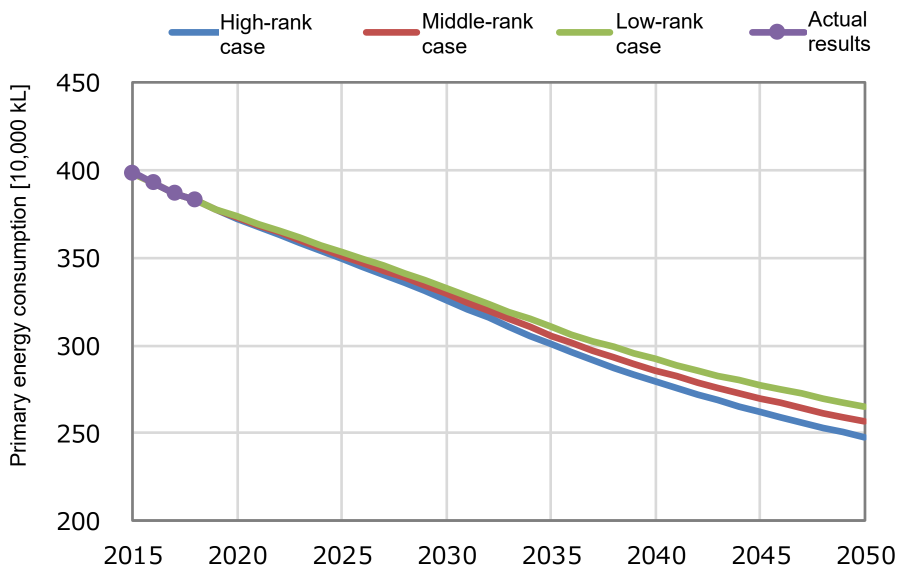


Fig. 2-63 Estimated primary energy consumption: Commercial air conditioning (central)

In addition, based on the above results, Fig. 2-64 and Table 2-30 show the energy-saving effects for each scenario above current fixed scenarios (primary energy consumption reduction effect), presuming that the current (FY2018) share of commercial heat pump air conditioning in stock and their flow efficiency remains constant going forward.

The amount of energy saved in the medium-order scenario for the FY2050 cross-section is estimated to be 680,000 kL/year, with the absorption refrigeration unit substitution effect making up 120,000 kL/year, and the effect of efficiency improvements made to heat pump air conditioning making up 560,000 kL/year.

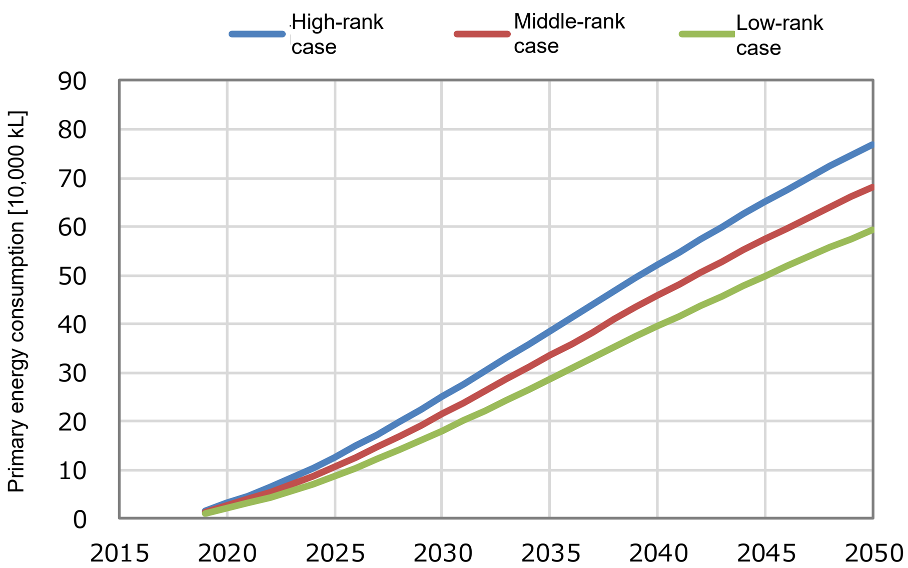


Fig. 2-64 Estimated energy-saving effects: Commercial air conditioning (central)

Table 2-30 Breakdown of energy-saving effects: Commercial air conditioning (central)

Scenario	Breakdown		Energy-saving effect (10,000 kL/year)			
			FY2020	FY2030	FY2040	FY2050
High-order scenario	Total		3	25	52	77
		Absorption refrigeration unit substitution effect	2	10	15	17
		Effects from improved heat pump air conditioning efficiency	1	14	37	60
Medium-order scenario	Total		2	21	46	68
		Absorption refrigeration unit substitution effect	2	8	11	12
		Effects from improved heat pump air conditioning efficiency	1	14	35	56
Low-order scenario	Total		2	18	39	59
		Absorption refrigeration unit substitution effect	1	5	6	7
		Effects from improved heat pump air conditioning efficiency	1	13	33	52

Note) The sum of values and the displayed totals do not always agree as numbers have been rounded.

Fig. 2-65 and Table 2-31 show estimations of the CO_2 reduction effect which is obtained by multiplying the above energy-saving effect by the CO_2 primary unit. As for fuels used in absorption refrigeration units, the FY2015 fuel consumption for air conditioning provided in the Energy & Economic Statistics Handbook was referenced to calculate the emission coefficient (which was presumed to remain constant) using the weighted averages of city gas and fuel oil A.

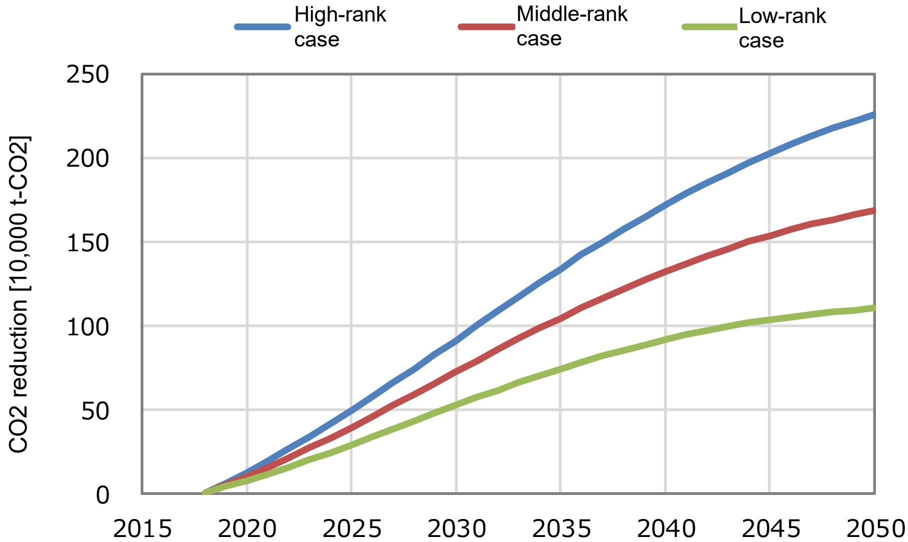


Fig. 2-65 Estimated CO_2 reduction effects: Commercial air conditioning (central)

Table 2-31 CO_2 reduction effects: Commercial air conditioning (central)

Scenario	Breakdown		CO2 reduction effect (10,000 t-CO2/year)			
			FY2020	FY2030	FY2040	FY2050
High-order scenario	Total		12	91	172	226
		Absorption refrigeration unit substitution effect	11	69	133	192
		Effects from improved heat pump air conditioning efficiency	1	22	39	34
Medium-order scenario	Total		9	72	132	169
		Absorption refrigeration unit substitution effect	8	50	94	133
		Effects from improved heat pump air conditioning efficiency	1	22	38	35
Low-order scenario	Total		7	52	92	110
		Absorption refrigeration unit substitution effect	6	31	54	73
		Effects from improved heat pump air conditioning efficiency	1	21	38	37

Note) The sum of values and the displayed totals do not always agree as numbers have been rounded.

(2) Individual (packaged air conditioner)

1) 1.Capacity shipped and capacity in stock

Fig. 2-66 and Fig. 2-67 show estimations of the capacity of packaged air conditioners shipped and in stock based on the above presumptions.

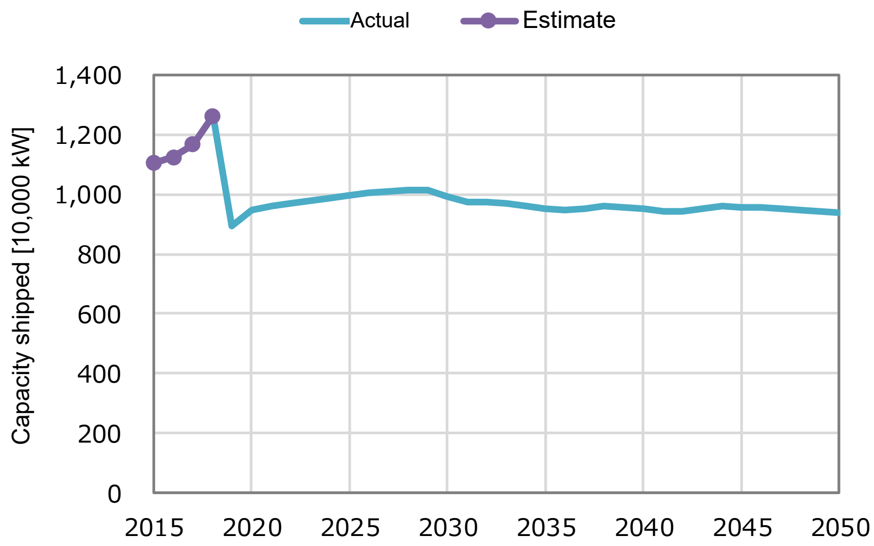


Fig. 2-66 Estimated capacity of commercial packaged air conditioners shipped

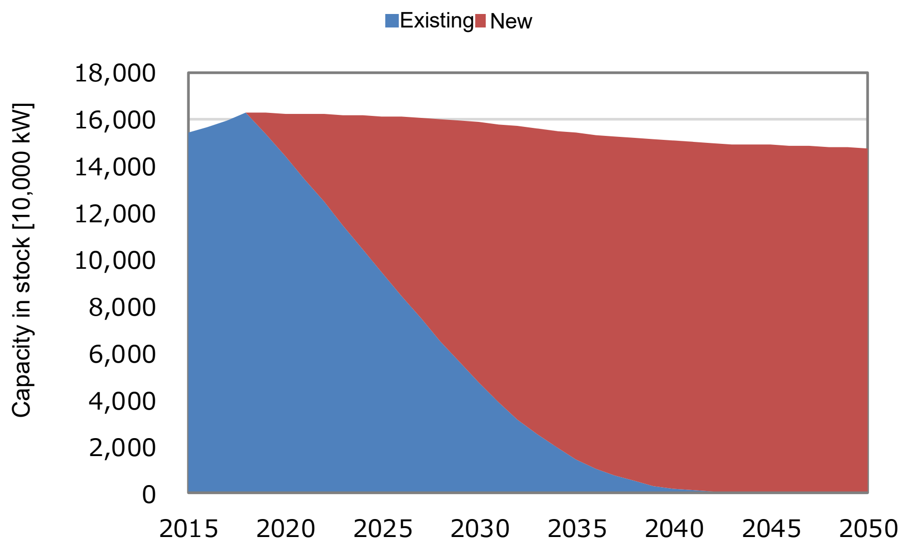


Fig. 2-67 Estimated capacity of commercial packaged air conditioners in stock

2) Primary energy consumption, energy-saving effect, CO2 reduction effect

Fig. 2-68 shows results of calculations of primary energy consumption made based on the above estimations of capacity shipped and in stock, presumed flow efficiency, operating time under full load equivalent, and electric power to primary energy conversion coefficient.

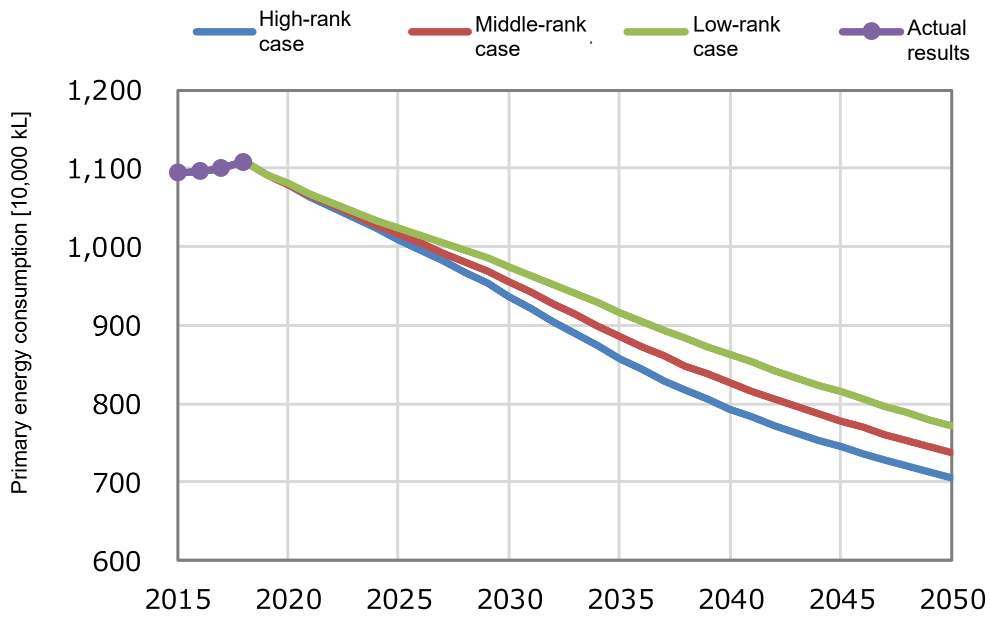


Fig. 2-68 Estimated primary energy consumption: Commercial air conditioning (individual)

In addition, based on the above results, the following Figure shows the energy-saving effects above current fixed scenarios (primary energy consumption reduction effect) for each scenario—scenarios which have been defined depending on the degree of efficiency improvements—presuming that the current (FY2018) flow efficiency remains constant going forward.

The amount of energy saved in the medium-order scenario for the FY2050 cross-section is estimated to be 1.93 million kL/year.

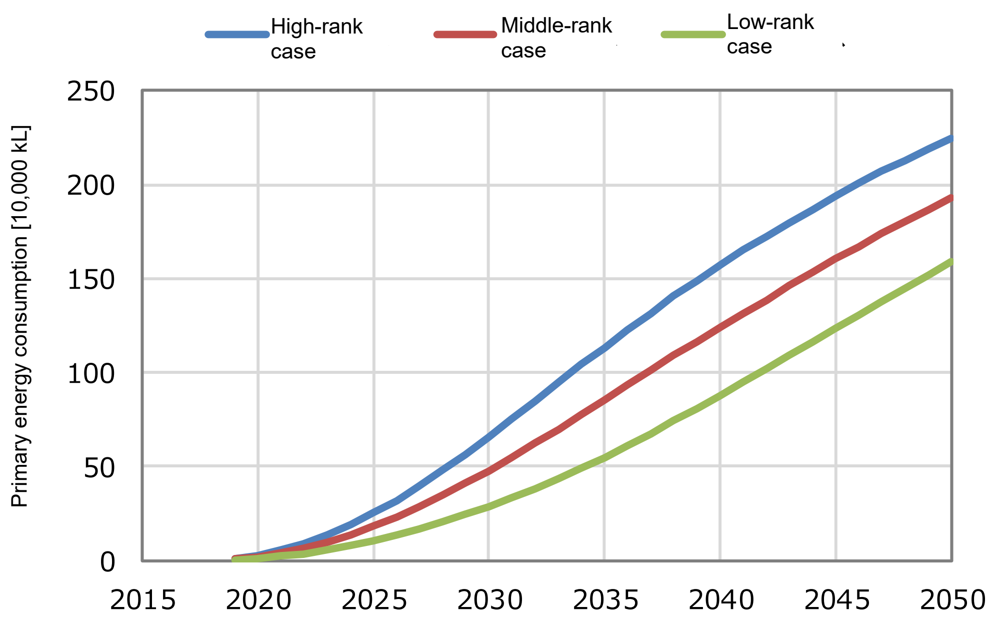


Fig. 2-69 Estimated energy-saving effects: Commercial air conditioning (individual)

Table 2-32 Energy-saving effect: Commercial air conditioning (individual)

Scenario	Energy-saving effect (10,000 kL/year)			
	FY2020	FY2030	FY2040	FY2050
High-order scenario	3	66	157	225
Medium-order scenario	2	48	124	193
Low-order scenario	1	28	88	159

Table 2-33 shows estimations of the CO2 reduction effect which is obtained by multiplying the above energy-saving effect by the CO2 primary unit. The CO2 reduction effect is expected to increase toward the latter half of the 2030s and then begin to decrease. This is because, with packaged air conditioners—＊for which there are no other equipment types that they can substitute for, and which are evaluated only for the efficiency improvements made to equipment that use electricity—the impact of their diminishing CO2 reduction effect per unit amount of energy saved becomes increasingly pronounced over the mid- to long-term as advancements are made in the reduction of the CO2 primary unit of electric power.

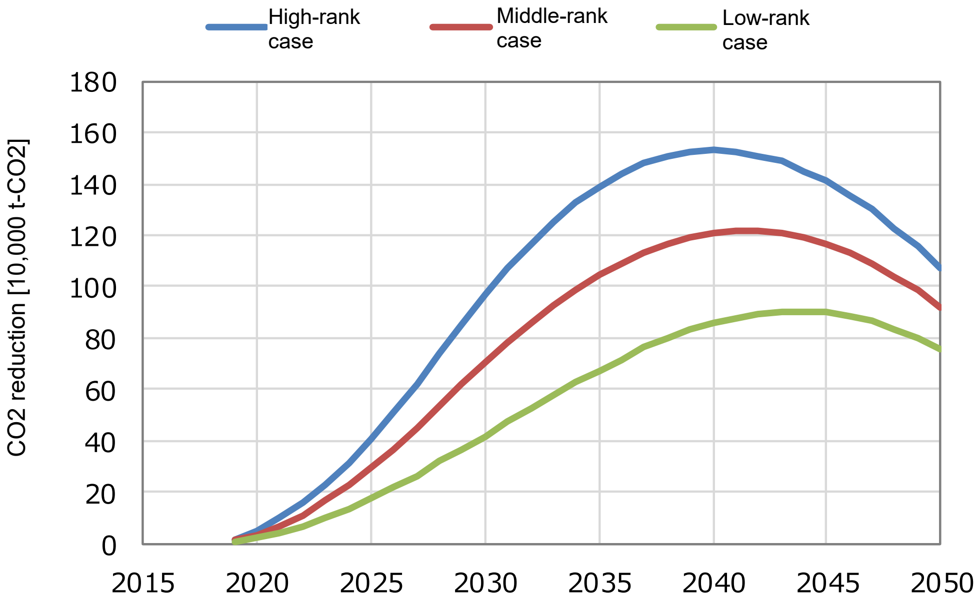


Fig. 2-70 Estimated CO2 reduction effects: Commercial air conditioning (individual)

Table 2-33 CO2 reduction effects: Commercial air conditioning (individual)

Scenario	CO2 reduction effect (10,000 t-CO2/year)			
	FY2020	FY2030	FY2040	FY2050
High-order scenario	5	97	153	107
Medium-order scenario	3	70	121	92
Low-order scenario	2	42	86	76

2.5 Industrial air conditioning

2.5.1 Preconditions

In our examination of industrial air conditioning, central and individual air conditioning are examined separately just as we have done with commercial air conditioning.

As for central air conditioning, the effects of substituting absorption refrigeration units with chilling units or turbo refrigeration units are evaluated. For individual air conditioning, the effects of improvements being made to the efficiency of packaged air conditioners are evaluated (No substitution is presumed for gas heat pump air conditioning).

As for turbo refrigeration units and absorption refrigeration units, the "for factory air conditioning" classification in the individual statistics from the Japan Refrigeration and Air-Conditioning Industry Association is presumed to refer to industrial air conditioning. As for chilling units, industrial air conditioning is presumed to refer to the 5% of units with 30 horsepower or more (Those not counted among the 5% of units with 30 horsepower or more were presumed to be commercial air-conditioning units). As for packaged air conditioners (PAC), the “air conditioners for facilities” classification in the individual statistics from the Japan Refrigeration and Air-Conditioning Industry Association is presumed to refer to industrial air conditioning.

Table 2-34 Industrial air conditioners evaluated

Type	Analyzed equipment	Statistical or documented equipment	
		Statistics	Equipment evaluated
Central	Industrial heat pump air conditioning	Japan Refrigeration and Air-Conditioning Industry Association Independent statistics	Turbo refrigeration units for factory air conditioning
			The 5% of chilling units with 30 horsepower or more
	Absorption refrigeration units	Japan Refrigeration and Air-Conditioning Industry Association Independent statistics	Absorption refrigeration units for factory air conditioning
Individual	Packaged Air conditioner	Japan Refrigeration and Air-Conditioning Industry Association Independent statistics	Air conditioning for facilities

2.5.2 Flow of calculations

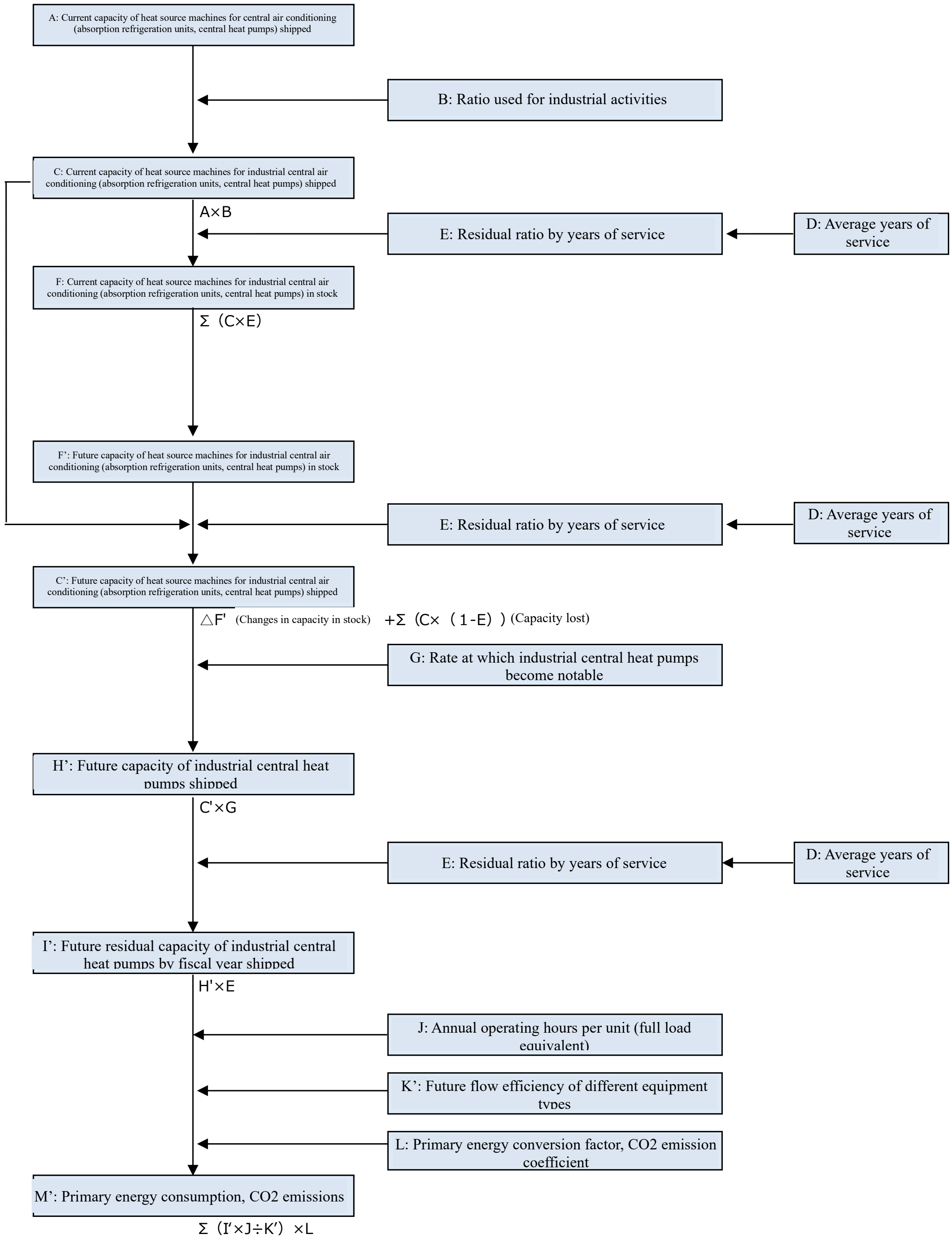


Fig. 2-71 Calculation flow for industrial air conditioning (central)

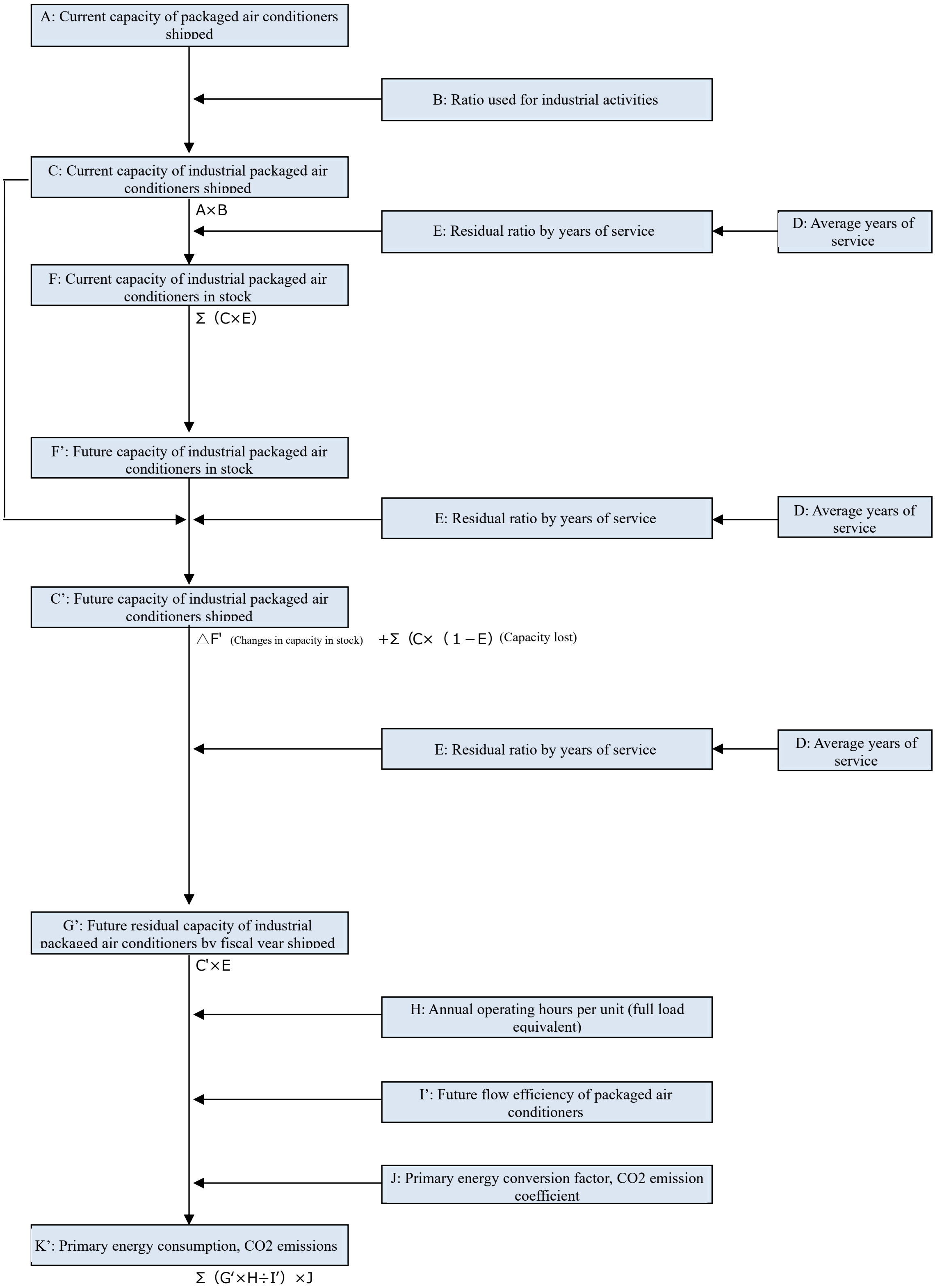


Fig. 2-72 Calculation flow for industrial air conditioning (individual)

2.5.3 Data used for calculation

(1) Market size for industrial air conditioners

1) Capacity of industrial air conditioners shipped

Fig. 2-73 shows the changes in the capacities of different industrial air conditioners shipped. A review of capacity shipped by equipment type shows that packaged air conditioners make up a share of roughly 70-80% of the total as was the case with commercial air conditioners. A breakdown of central air conditioning shows that the shares of turbo refrigeration and absorption refrigeration units were roughly the same in the 1990s, with turbo refrigeration units growing their share since FY2000.

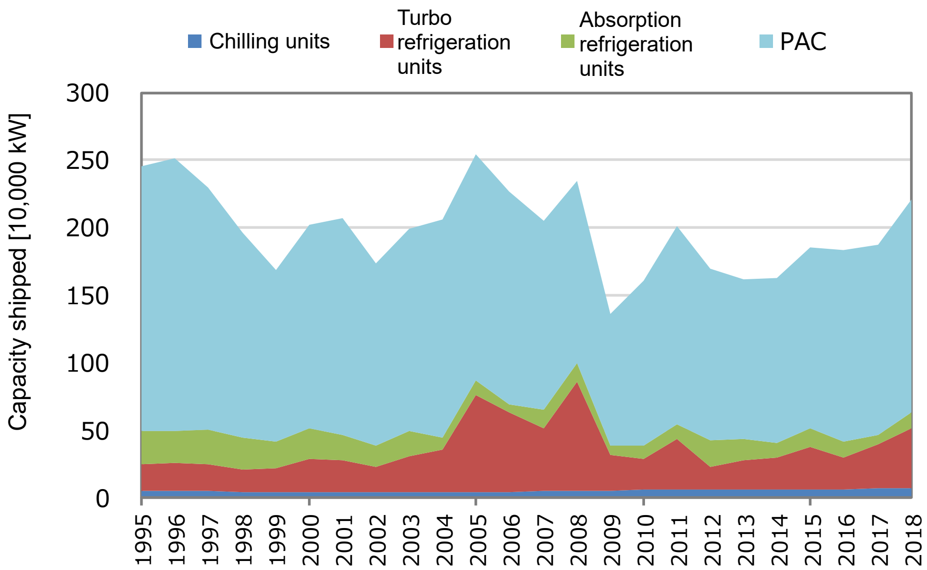


Fig. 2-73 Changes in the capacities of industrial air conditioners shipped (excluding GHP)

2) Average years of service, residual curve

The average years of service and residual curves of different air conditioners were presumed to be comparable to those of commercial air conditioners.

3) Market size for industrial air conditioners (capacity in stock)

The residual capacity for each year is estimated by multiplying the above-mentioned annual capacity shipped by the residual ratio, and the cumulative result is regarded as the current capacity of industrial air conditioners in stock.

Estimations of the future capacity of industrial air conditioners in stock are shown in Fig. 2-74. These estimations are based on the presumption that the capacity outlook of industrial air conditioners in stock will remain flat for the present time, and the share of central and individual (packaged air conditioner) units will remain unchanged going forward.

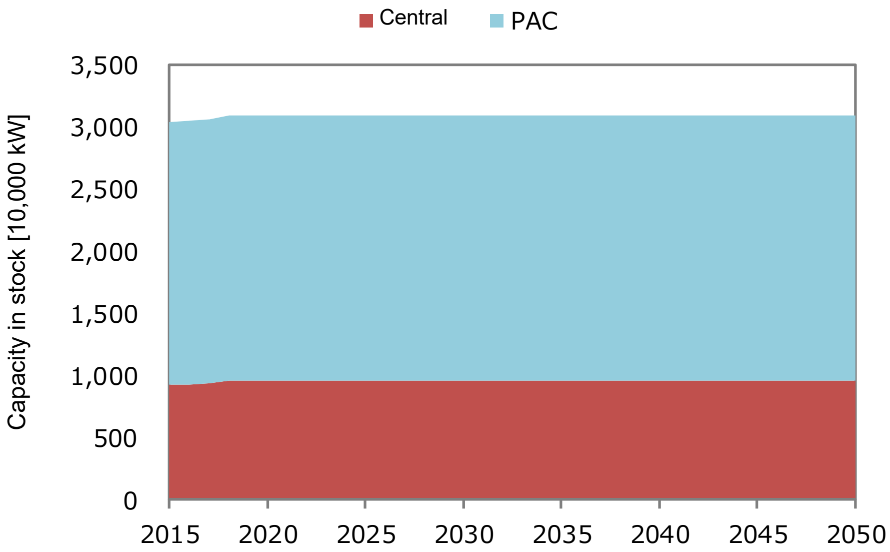


Fig. 2-74 Future capacity of industrial air conditioning in stock (excluding GHP)

(2) Specifications of industrial air conditioners

1) Flow efficiency of industrial air conditioners

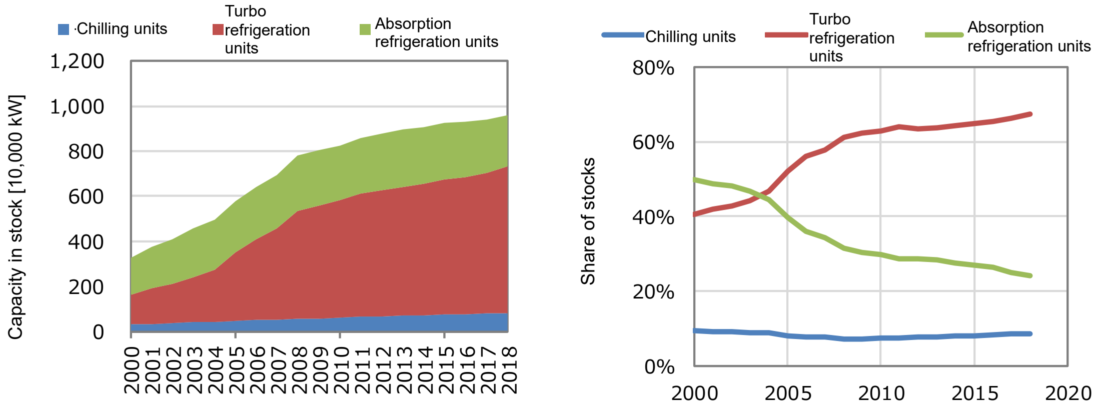
The flow efficiency of industrial air conditioners is presumed to be the same as that of commercial air conditioners. That is, while future efficiency improvements were uniformly taken into account in estimations for turbo refrigeration units, packaged air conditioners and absorption refrigeration units, packaged air conditions were defined with three scenarios that depend on the degree of efficiency improvements made.

2) Full load equivalent operating time

The full load equivalent operating time of industrial air conditioners was defined as 1,100 h/year based on presumptions stated in the long-term energy supply and demand outlook.

(3) Share of industrial heat pump air conditioners (chilling units, turbo refrigeration units) in stock

Shown below are estimations of the stock of chilling units, turbo refrigeration units, and absorption refrigeration units made by integrating records of actual adoption since FY1994 obtained from statistical data. After entering the 2000s, the share of absorption refrigeration units declined and the share turbo refrigeration units increased. As of FY2018, chilling units and turbo refrigeration units account for a combined share of roughly 76%.



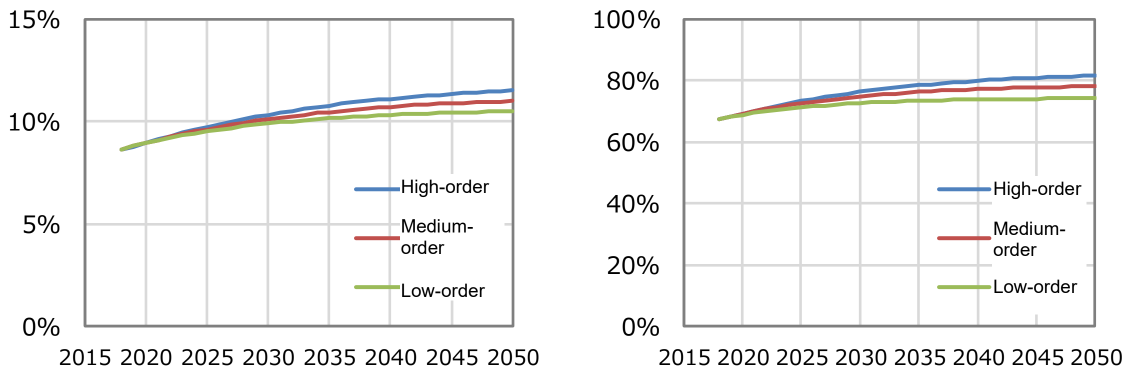
(Left: Capacity in stock, Right: Share of stocks)

Fig. 2-75 Status of adoption of industrial air conditioning (central)

The future share of chilling units and turbo refrigeration units in stock were estimated by applying a logistic curve to changes in the share of each of these types of units since FY2009. In applying logistic regression, as shown in Table 2-35, three scenarios—high-order, medium-order, and low-order scenarios—were presumed as upper asymptotic value limits of the share of heat pumps. The share of chilling units and turbo refrigeration units were presumed to remain largely unchanged from current levels. Furthermore, it was presumed that the upper asymptotic value limit will be approached at around FY2050, i.e, in roughly three product life cycles.

Table 2-35 Presumed upper limit of industrial heat pump air conditioning (central) adoption

Scenario	Upper limit of industrial heat pump air conditioning (central) adoption
High-order scenario	Capacity in stock × 95%
Medium-order scenario	Capacity in stock × 90%
Low-order scenario	Capacity in stock × 85%



(Left: Chilling units, Right: Turbo refrigeration units)

Fig. 2-76 Presumed share of industrial air conditioners (central) in stock

2.5.4 Calculation results

(1) Central

1) Capacity shipped and capacity in stock

Fig. 2-77 - Fig. 2-80 show estimations of the capacity of chilling units and turbo refrigeration units shipped and in stock based on the above presumptions.

For the FY2050 cross-section in the medium-order scenario, the capacity of chilling units shipped and in stock will reach 70,000 kW and 1.06 million kW, respectively, and the capacity of turbo refrigeration units shipped and in stock will reach 370,000 kW and 7.52 million kW, respectively.

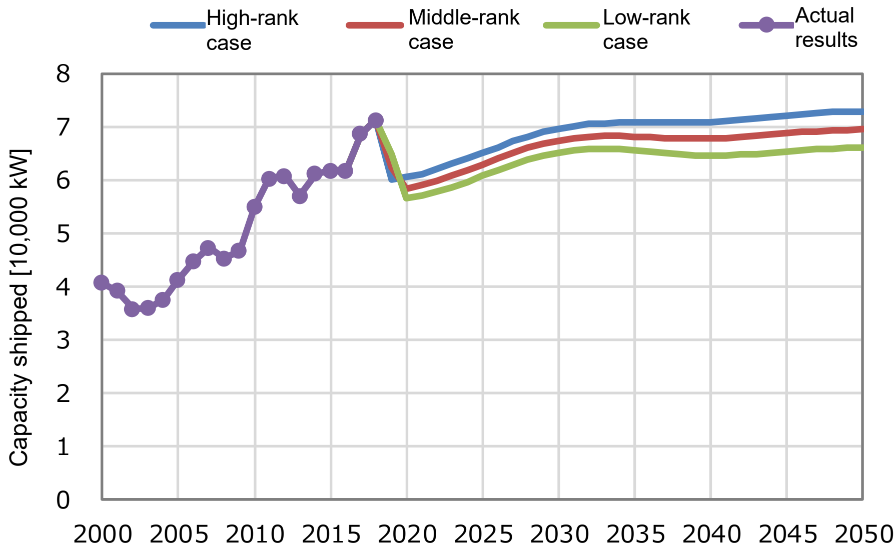


Fig. 2-77 Estimated capacity of industrial chilling units shipped

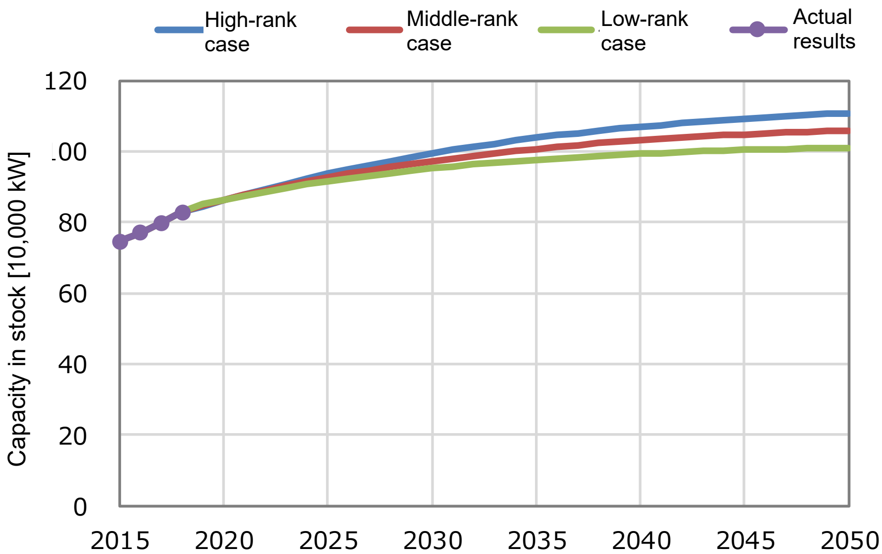


Fig. 2-78 Estimated capacity of industrial chilling units in stock

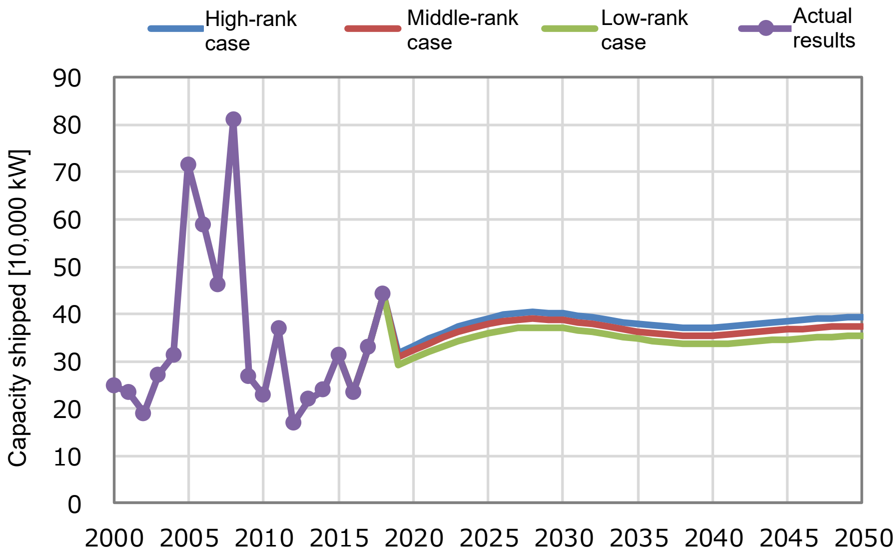


Fig. 2-79 Estimated capacity of industrial turbo refrigeration units shipped

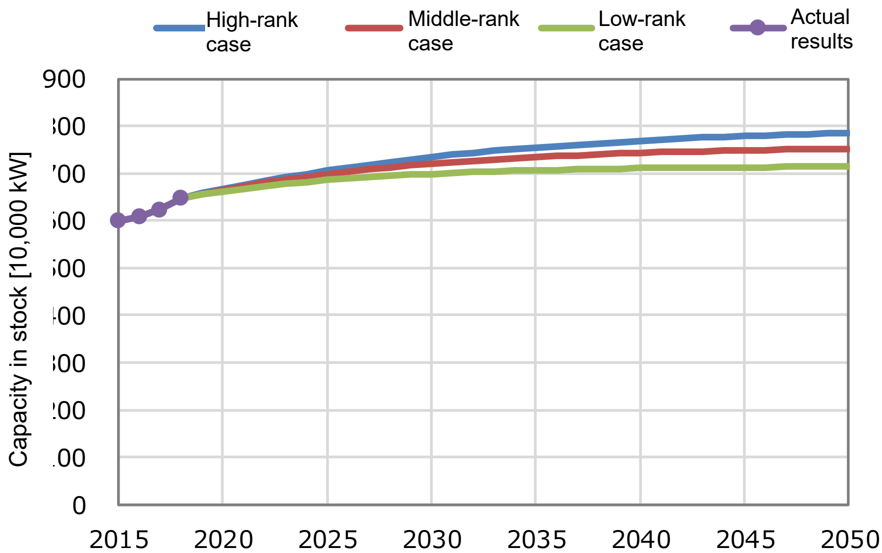


Fig. 2-80 Estimated capacity of industrial turbo refrigeration units in stock

2) Primary energy consumption, energy-saving effect, CO2 reduction effect

Fig. 2-81 shows results of calculations of primary energy consumption made based on the above estimations of capacity shipped and in stock, presumed flow efficiency, operating time under full load equivalent, and electric power to primary energy conversion coefficient.

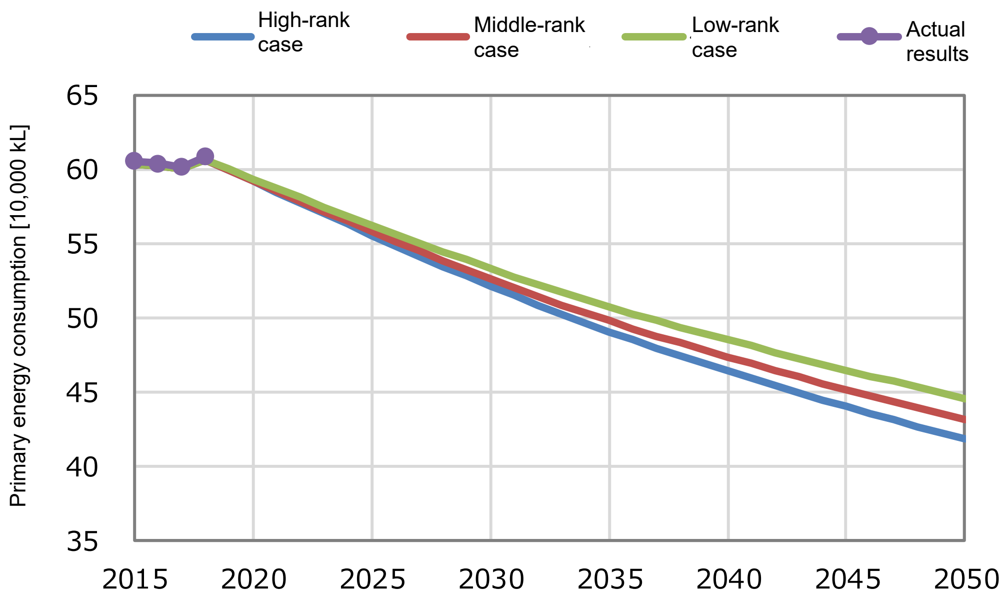


Fig. 2-81 Estimated primary energy consumption: Industrial air conditioning (central)

In addition, based on the above results, Fig. 2-82 shows the energy-saving effects for each scenario above current fixed scenarios (primary energy consumption reduction effect), presuming that the current (FY2018) share of industrial heat pump air conditioning in stock and their flow efficiency remains constant going forward.

The amount of energy saved in the medium-order scenario for the FY2050 cross-section is estimated to be 130,000 kL/year, with the absorption refrigeration unit substitution effect making up 30,000 kL/year, and the effect of efficiency improvements made to heat pump air conditioning making up 100,000 kL/year.

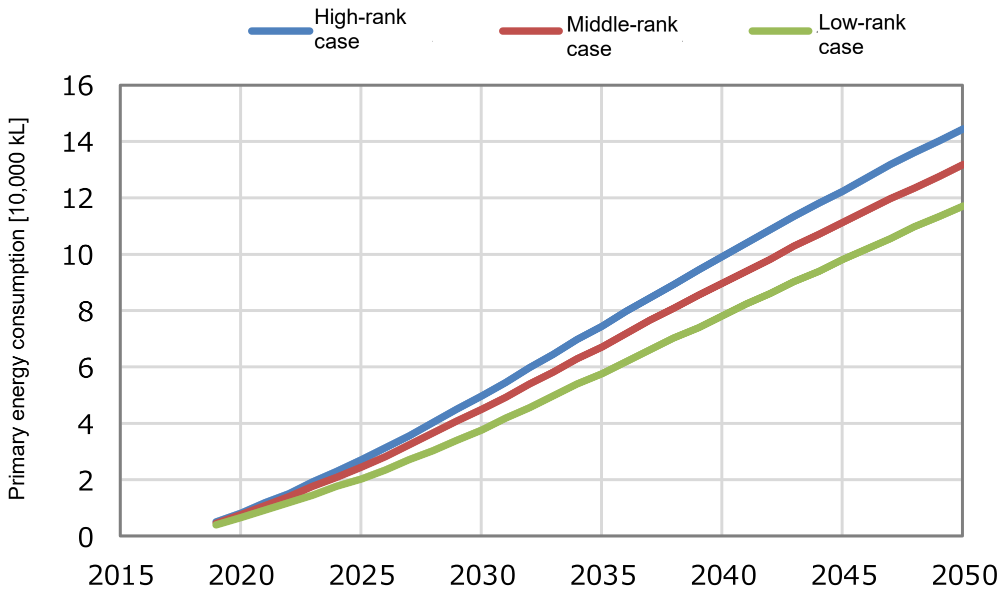


Fig. 2-82 Estimated energy-saving effects: Industrial air conditioning (central)

Table 2-36 Breakdown of energy-saving effects: Industrial air conditioning (central)

Scenario	Breakdown	Energy-saving effect (10,000 kL/year)			
		FY2020	FY2030	FY2040	FY2050
High-order scenario	Total	1	5	10	14
	Absorption refrigeration unit substitution effect	1	3	4	4
	Effects from improved heat pump air conditioning efficiency	0	2	6	10
Medium-order scenario	Total	1	4	9	13
	Absorption refrigeration unit substitution effect	1	2	3	3
	Effects from improved heat pump air conditioning efficiency	0	2	6	10
Low-order scenario	Total	1	4	8	12
	Absorption refrigeration unit substitution effect	0	2	2	2
	Effects from improved heat pump air conditioning efficiency	0	2	6	10

Note) The sum of values and the displayed totals do not always agree as numbers have been rounded.

Fig. 2-83 and Table 2-37 show estimations of the CO2 reduction effect which is obtained by multiplying the above energy-saving effect by the CO2 primary unit. As for fuels used in absorption refrigeration units, the breakdown of types of fuel for industrial boilers provided in the Comprehensive Energy Statistics was referenced for convenience to calculate the emission coefficient (which was presumed to remain constant) using the weighted averages of city gas and fuel oil A.

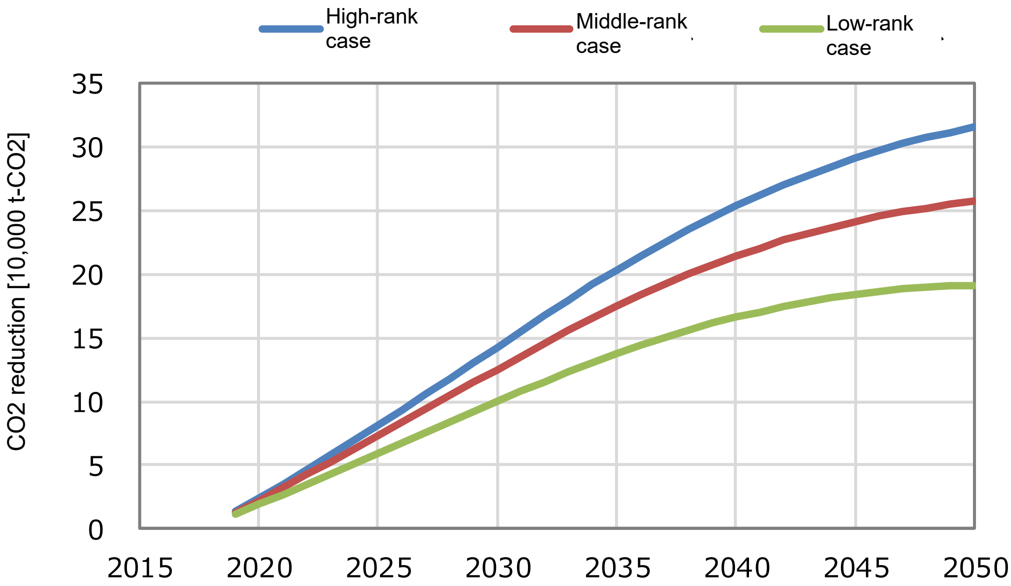


Fig. 2-83 Estimated CO2 reduction effects: Industrial air conditioning (central)

Table 2-37 Breakdown of CO2 reduction effects: Industrial air conditioning (central)

Scenario	Breakdown		CO2 reduction effect (10,000 t-CO2/year)			
			FY2020	FY2030	FY2040	FY2050
High-order scenario	Total		2	14	25	32
		Absorption refrigeration unit substitution effect	2	11	19	26
		Effects from improved heat pump air conditioning efficiency	0	3	6	5
Medium-order scenario	Total		2	12	21	26
		Absorption refrigeration unit substitution effect	2	9	15	20
		Effects from improved heat pump air conditioning efficiency	0	3	6	6
Low-order scenario	Total		2	10	17	19
		Absorption refrigeration unit substitution effect	2	7	10	13
		Effects from improved heat pump air conditioning efficiency	0	3	6	6

Note) The sum of values and the displayed totals do not always agree as numbers have been rounded.

(2) Individual (packaged air conditioner)

1) Capacity shipped and capacity in stock

Fig. 2-84 and Fig. 2-85 show estimations of the capacity of packaged air conditioners shipped and in stock based on the above presumptions.

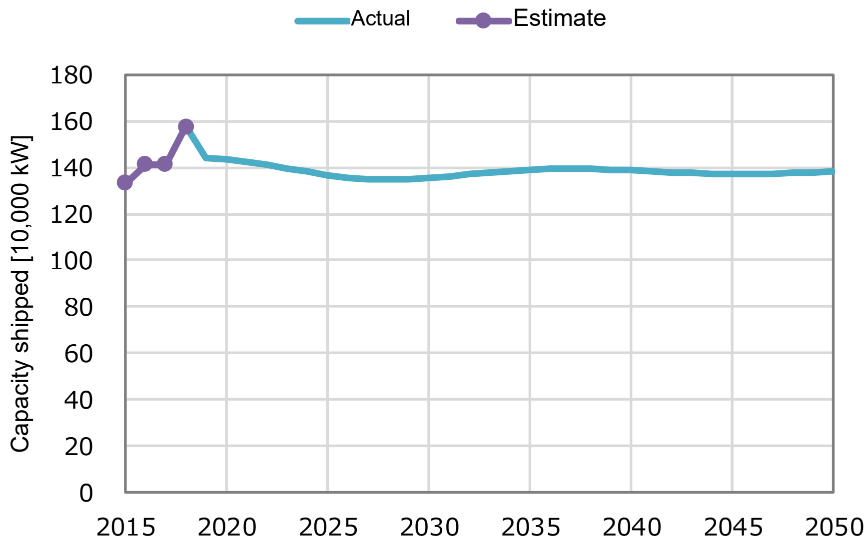


Fig. 2-84 Estimated capacity of industrial packaged air conditioners shipped

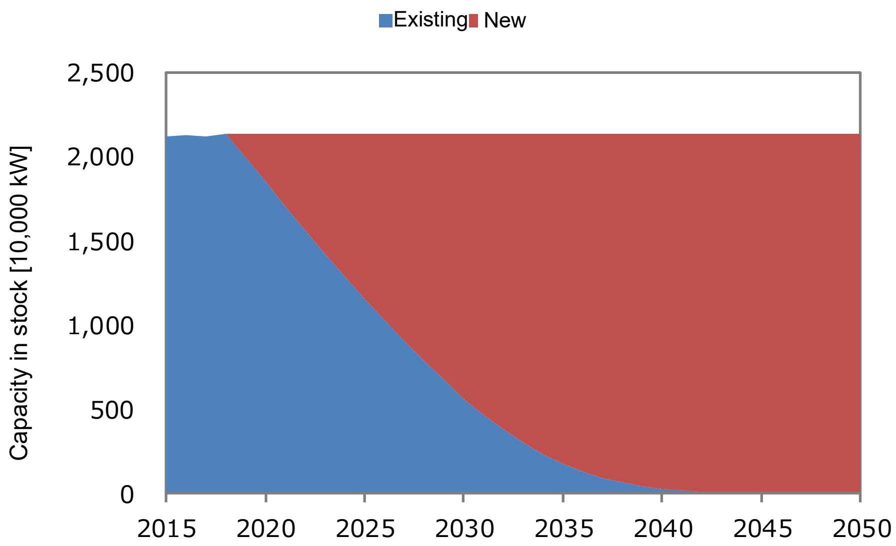


Fig. 2-85 Estimated capacity of industrial packaged air conditioners in stock

2) Primary energy consumption, energy-saving effect, CO_2 reduction effect

Fig. 2-86 shows results of calculations of primary energy consumption made based on the above estimations of capacity shipped and in stock, presumed flow efficiency, operating time under full load equivalent, and electric power to primary energy conversion coefficient.

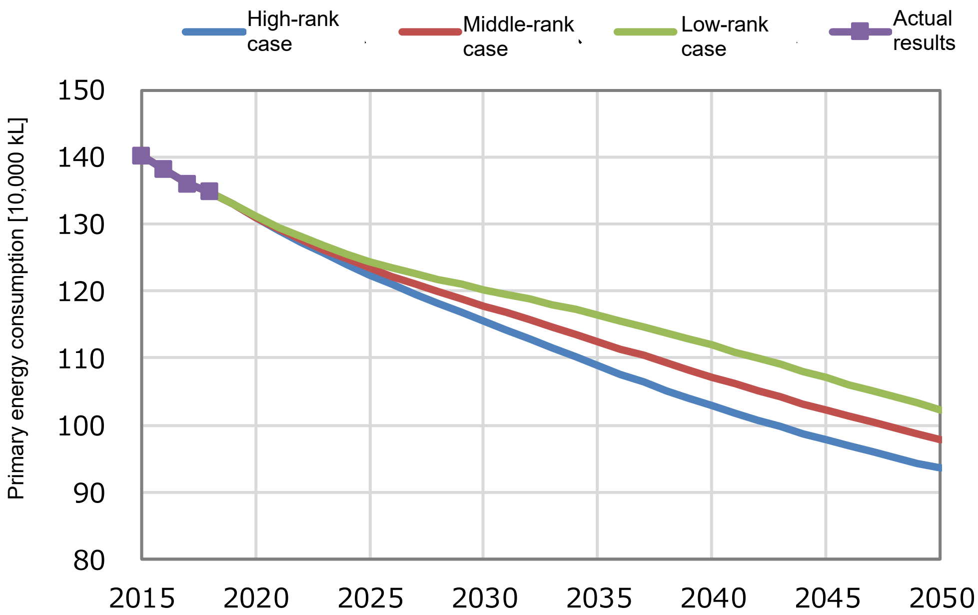


Fig. 2-86 Estimated primary energy consumption: Industrial air conditioning (individual)

In addition, based on the above results, the following Figure shows the energy-saving effects above current fixed scenarios (primary energy consumption reduction effect) for each scenario—scenarios which have been defined depending on the degree of efficiency improvements—presuming that the current (FY2018) flow efficiency remains constant going forward.

The amount of energy saved in the medium-order scenario for the FY2050 cross-section is estimated to be 260,000 kL/year.

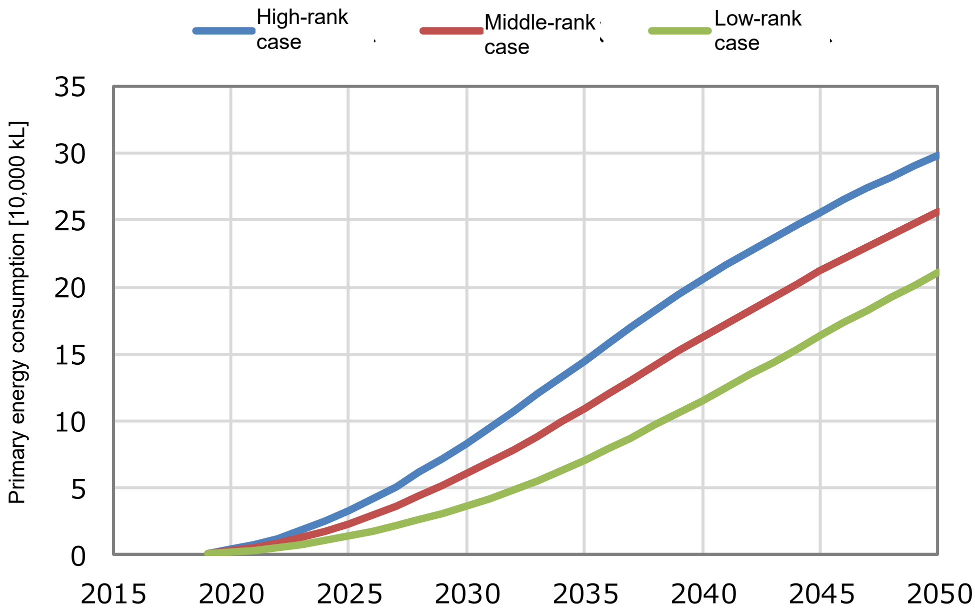


Fig. 2-87 Estimated energy-saving effects: Industrial air conditioning (individual)

Table 2-38 Energy-saving effect: Industrial air conditioning (individual)

Scenario	Energy-saving effect (10,000 kL/year)			
	FY2020	FY2030	FY2040	FY2050
High-order scenario	0	8	21	30
Medium-order scenario	0	6	16	26
Low-order scenario	0	4	12	21

Fig. 2-88 and Table 2-39 show estimations of the CO_2 reduction effect which is obtained by multiplying the above energy-saving effect by the CO_2 primary unit. The CO_2 reduction effect is expected to increase toward the latter half of the 2030s and then begin to decrease. This is because, with packaged air conditioners—which cannot be substituted by other types of units and are evaluated only for the efficiency improvements made to equipment that use electricity—the impact of their diminishing CO_2 reduction effect per unit amount of energy saving becomes increasingly pronounced over the mid- to long-term as advancements are made to the reduction in CO_2 primary unit of electric power.

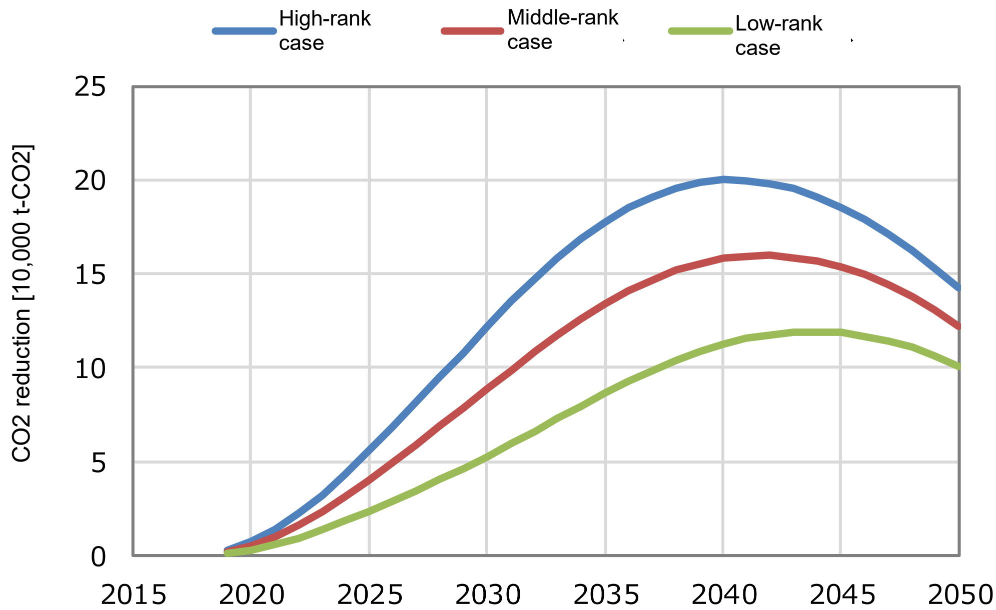


Fig. 2-88 Estimated CO_2 reduction effects: Industrial air conditioning (individual)

Table 2-39 CO_2 reduction effects: Industrial air conditioning (individual)

Scenario	CO2 reduction effect (10,000 t-CO2/year)			
	FY2020	FY2030	FY2040	FY2050
High-order scenario	1	12	20	14
Medium-order scenario	0	9	16	12
Low-order scenario	0	5	11	10

2.6 Industrial heating

2.6.1 Preconditions

(1) Equipment to be evaluated

With regard to industrial heating, the decision was made to evaluate the effects of substituting industrial heat pumps for industrial boilers. The industrial heating equipment to be evaluated are shown in Table 2-40.

"Industrial heat pumps" are defined to be those that have actually shipped as recorded in reference materials used in joint meetings held by the Global Environment Working Group, Central Environment Council, and the Global Environment Subcommittee, Committee on industrial Science and Technology Policy and Environment, Industrial Structure Council.

Industrial boilers were presumed to be general purpose boilers as defined in the Current Production Statistics, and "small once-through boilers" that have actually shipped as recorded in the "Heating Equipment Year Book" issued by the Japan Heating Industrial Association. As for "small once-through boilers," 50% of these were presumed to be for industrial heating, and the remaining 50% for commercial hot water supply based on presumptions stated in the METI report "2014 infrastructure development project for advancing the streamlining of energy use (survey on energy-saving technology in industrial furnaces and such)."

Table 2-40 Industrial heating equipment evaluated

Analyzed equipment	Statistical or documented equipment	
	Statistics or documents	Equipment evaluated
Industrial heat pumps	Individual statistics from the Japan Refrigeration and Air-Conditioning Industry Association Progress Report of the Global Warming Countermeasures Plan in FY2018 (efforts associated with measures being carried out by METI, and the Ministry of the Environment) (Detailed version)	Industrial heat pumps
Industrial boilers	Current Production Statistics	General purpose boilers
	"Heating Equipment Year Book," Japan Heating Industrial Association	50% of small once-through boilers

(2) Defining market segments

In industrial sector, boiler steam is often used for process heating. It is used in a wide range of applications including hot water supply, drying, washing, boiling, steaming, low-temperature heating (fermentation cultivation, etc.), and direct heating (heating of pots and such).

Heat pumps can be applied primarily to low-temperature applications below 100ºC, and are often used for hot water supply, cleaning, drying, and low-temperature heating. As for air conditioning, while there are many industries that apply stricter controls, it is believed that heat pumps can basically be applied to these applications as well. In addition, the commercial availability of heat pumps that run at temperatures of 100ºC and higher has been growing in recent years.

As such, with regard to energy used in industry for boilers, we have performed calculations on the outlook for widespread take-up and energy-saving effects of heat pumps for applications under 100ºC, including "factory air conditioning," "heating (low-temperature heating for fermentation and cultivation, and hot water supply and washing)," and "low-temperature drying (under 100ºC)," as well as the same for "high-temperature" applications where high-temperature heat pumps producing heat 100ºC and higher can be applied. Because hot water supply and cleaning have much in common with low-temperature heating in that water is heated to temperatures in the tens of degrees centigrade, these applications were grouped into a single group: "heating."

2.6.2 Flow of calculations

Fig. 2-89 shows the flow for calculating the outlook for widespread take-up of industrial heat pumps in the industrial heating market.

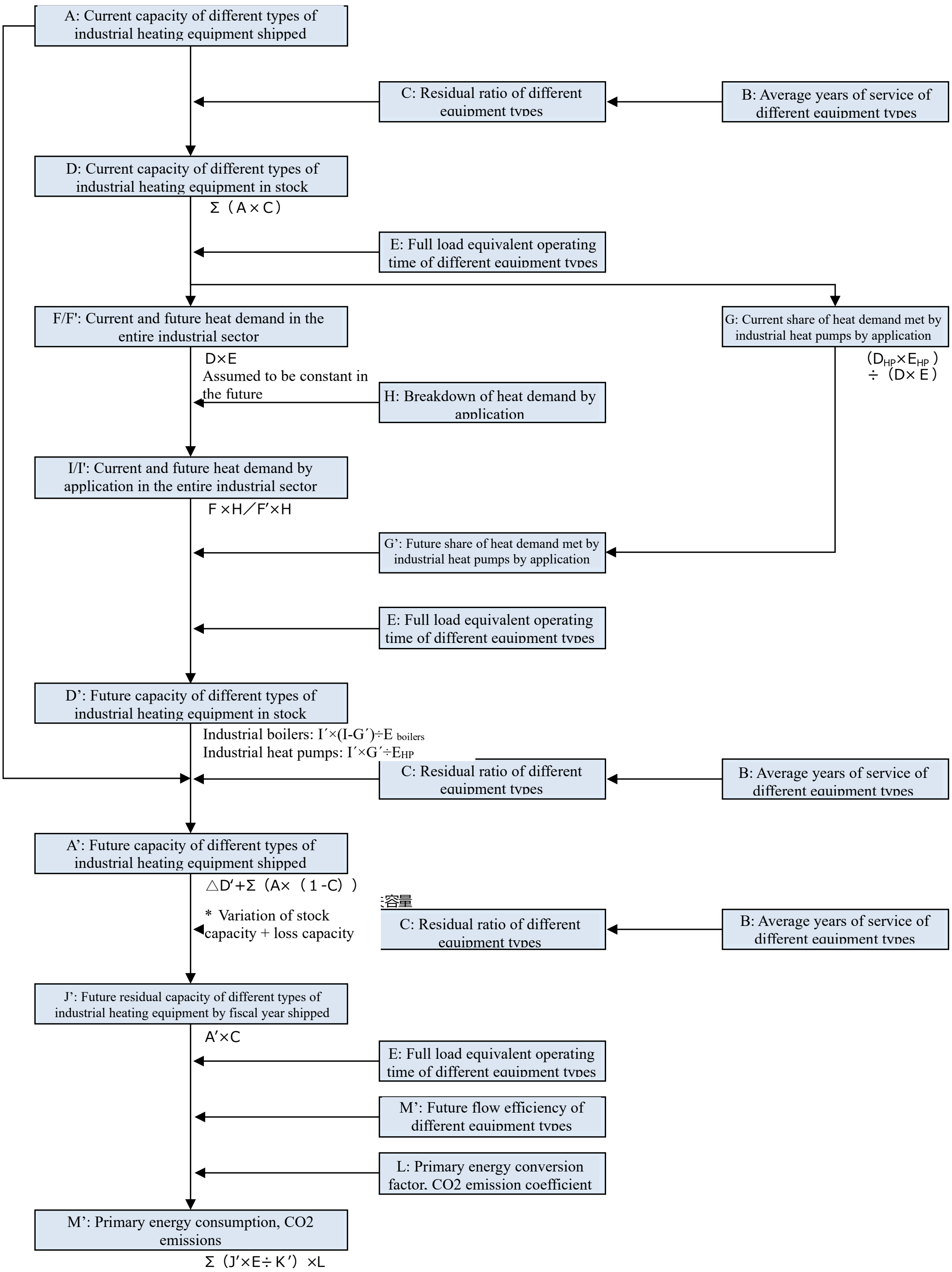


Fig. 2-89 Flow for calculating the outlook for widespread take-up of industrial heat pumps in the industrial heating market

2.6.3 Data used for calculation

(1) Market size for industrial heating (heat demand in the industrial sector)

The current market size for industrial heating (heat demand in the industrial sector) was estimated by calculating the capacity in stock, taking into account the residual component for different years of service for the capacity of industrial heating equipment currently shipped, and by multiplying this by their full load equivalent operating times. The market size for different applications was calculated by apportioning the estimated heat demand by application (factory air conditioning, heating, low temperature drying, high temperature applications) using existing statistics and other data.

Furthermore, market size at the present time (FY2018) is presumed to remain flat in future projections.

1) Current capacity of industrial heating equipment shipped

Fig. 2-90 shows the changes to date in the capacity of industrial heating equipment shipped.

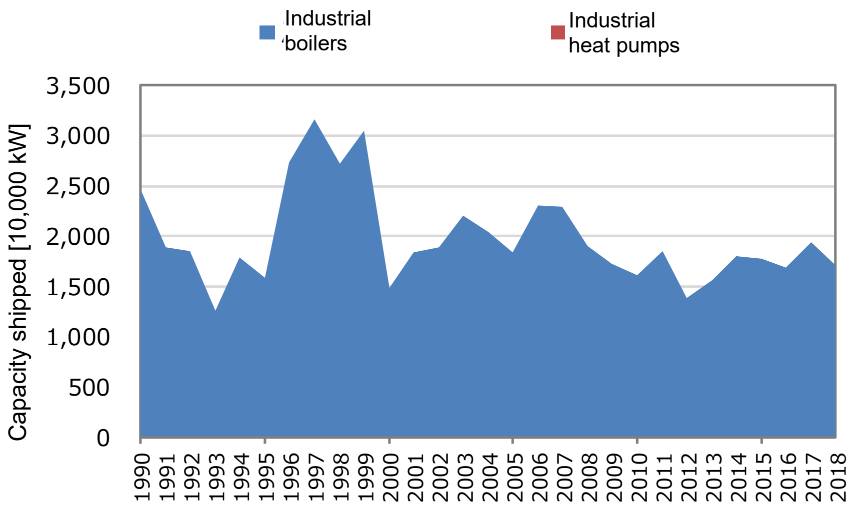


Fig. 2-90 Changes to date in the capacity of industrial heating equipment shipped.

As shown in Table 2-40, the actual records of shipment of industrial heat pumps were defined based on individual statistics from the Japan Refrigeration and Air-Conditioning Industry Association, and the Progress Report of the Global Warming Countermeasures Plan in FY2018 (efforts associated with measures being carried out by METI, and the Ministry of the Environment) (Detailed version). Shipments of industrial boilers were defined based on the Current Production Statistics, and the "Heating Equipment Year Book" issued by the Japan Heating Industrial Association.

The above data shows capacity-based shipment records for industrial heat pumps and industrial boilers for general use, but show only unit-based records for the shipment of small once-through boilers.

Therefore, average single unit capacities for small once-through boilers were defined as shown in Table 2-41.

Table 2-41 Presumed average single unit capacities of small once-through boilers

Equipment	Classification	Average single unit capacity*	
Small once-through boilers	Small boilers	2t/h	1,250 kW
	Simple boilers	0.35 t/h	220 kW

Note) Converted as 2,257 kJ/kg x 1,000 kg/t ÷ 3,600 kJ/kWh = 627 kW/(t/h), where the evaporative latent heat of water is presumed to be 2,257 kJ/kg.

2) Average years of service, residual curve

The presumed average years of service according to an HPTCJ survey are shown in Table 2-42.

Table 2-42 Presumed average years of service of industrial heating equipment

Application	Average years of service
Industrial boilers	15 years
Industrial heat pumps	12 years

Residual curves (residual ratio by years of service) are expressed using the following formula. Parameters α and β that represent the shape of the residual curve must be defined. Here, these were defined so that the average years of service of industrial heating equipment estimated from the residual curve is consistent with the average years of service presumed in the description above.

$$Residual\ ratio = e^{-\alpha(\text{Years elapsed}^{\beta})}$$

Fig. 2-91 shows the residual curves defined based on the above.

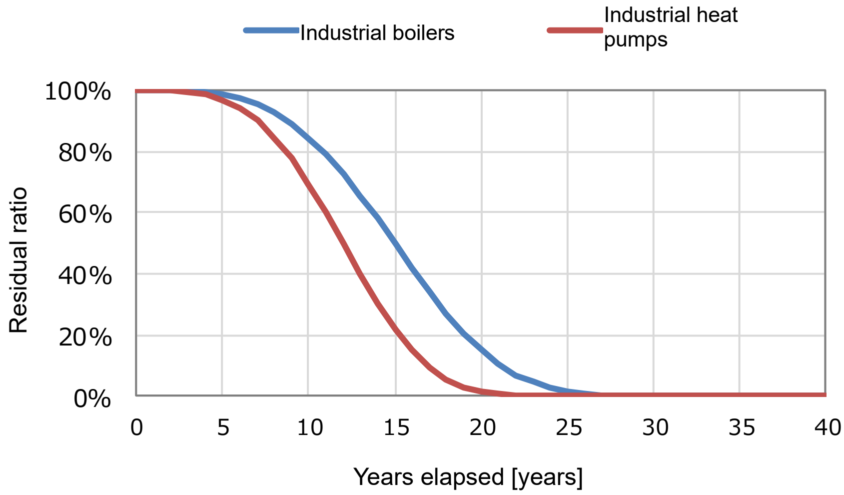


Fig. 2-91 Residual curves of industrial heating equipment

3) Full load equivalent operating time of industrial heating equipment

The full load equivalent operating time of industrial heating equipment was defined as 1,700 h/year based on the "Heat Pumps and Thermal Storage White Paper," and shown in Table 2-43.

Table 2-43 Full load equivalent operating time of industrial heating equipment

Data used		How values were defined
[1] Daily operating hours	16h/year	While hours of operation will vary depending on operating conditions at each particular factory, it is believed that the majority of factories either run for 24 hours, or only for 8 hours during the day. For this reason, the intermediate value is used here.
[2] Annual days of operation	300 days/year	Defined based on the presumption that Sundays are regular holidays for factories on average.
[3] Operating rate	35%	Presumed value
[4] Full load equivalent operating time	Approximately 1,700h/year	Defined as [1] × [2] × [3]

4) Breakdown of heat demand by application in the industrial sector

This breakdown of heat demand by application in the industrial sector (factory, air conditioning, heating, low-temperature drying, high-temperature) was estimated by using heat demand by industry (amount of self-generated steam) that can be discerned from the "2018 Annual Energy Consumption Statistics (table of estimates including current consumption statistics, such as for oil)" to weight-average the composition ratio of heat demand by application in different industries described in the "Heat Pumps and Thermal Storage White Paper."

Based on this, the breakdown was estimated to consist of air conditioning at 15%, heating at 11%, low-temperature drying at 12%, and high-temperature at 62% as shown in Table 244.

Table 2-44 Breakdown of heat demand by application in the industrial sector

Industry	Heat demand (TJ)	Composition ratio of heat demand by application			
		Factory air conditioning	Heating	Low-temperature drying	High-temperature
Food product production	108,192	15%	15%	30%	40%
Manufacture of beverage, tobacco, and forage	32,104	30%	30%	20%	20%
Textile industry	58,533	20%	60%	0%	20%
Manufacture of lumber and wooden products (excluding furniture)	29,155	22%	16%	9%	53%
Manufacture of furniture and accessories	645	22%	16%	9%	53%
Manufacture of pulp, paper, and processed paper products	420,457	10%	10%	25%	55%
Printing and associated industries	3,224	22%	16%	9%	53%
Chemical engineering	480,808	20%	10%	10%	60%
Manufacture of petroleum and coal products	236,039	10%	10%	0%	80%
Manufacture of plastic products (excluding products referenced elsewhere)	120,144	30%	5%	10%	55%
Manufacture of rubber products	15,669	20%	5%	0%	75%
Manufacture of tanned leather, products thereof, and fur	152	22%	16%	9%	53%
Ceramics industry and manufacture of earth/stone products	71,687	10%	5%	5%	80%
Steel industry	194,289	7%	3%	0%	90%
Manufacture of non-ferrous metals	11,991	10%	5%	0%	85%
Manufacture of metal products	8,274	22%	16%	9%	53%
Manufacture of mechanical equipment for generic applications	1,377	40%	10%	10%	40%
Manufacture of mechanical equipment for production	1,005	40%	10%	10%	40%
Manufacture of mechanical equipment for commercial use	1,239	40%	10%	10%	40%
Manufacture of electronic components, devices, and electronic circuits	8,373	60%	20%	5%	15%
Manufacture of electric mechanical equipment	2,862	60%	20%	5%	15%
Manufacture of mechanical equipment for information communication	141	60%	20%	5%	15%
Manufacture of mechanical equipment for transportation	10,518	30%	30%	10%	30%
Other manufacturing	1,289	22%	16%	9%	53%
Averages weighted by heat demand		15%	11%	12%	62%

5) Heat demand in the industrial sector

Fig. 2-92 shows estimations of future heat demand by application in the industrial sector based on the above presumptions. The total values shown here are roughly consistent with estimations of heat demand in the industrial sector based on energy consumption statistics.

As mentioned above, this is presumed to remain flat at the present time (FY2018) in future projections.

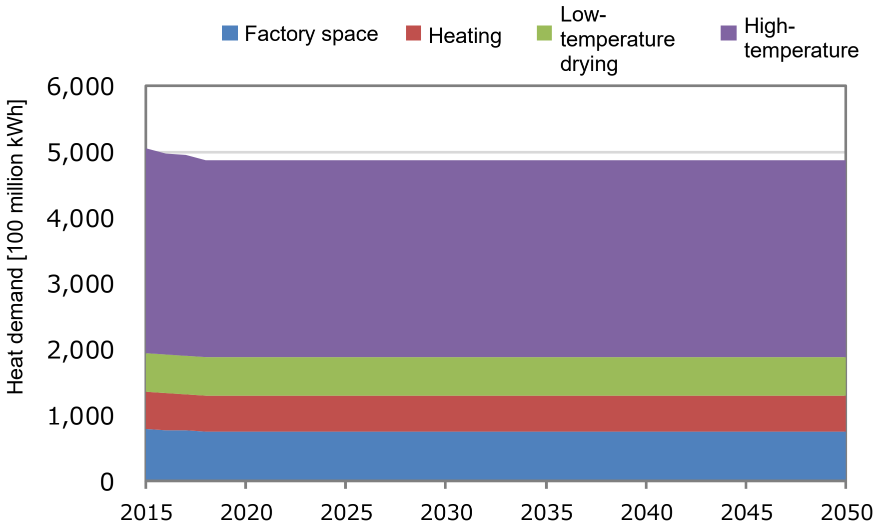


Fig. 2-92 Future changes in heat demand by application in the industrial sector

(2) Share of heat demand met by industrial heat pumps

The current share of heat demand met by industrial heat pumps was estimated by calculating the heat demand met by different types of equipment based on records of actual shipment of industrial heating equipment and residual curves discussed in (1), and their presumed full load equivalent operating times.

Future projections were defined by applying a logistic curve to current changes in the share of heat demand that is being met by industrial heat pumps. In applying logistic regression, three scenarios—high-order, medium-order, and low-order scenarios—were presumed for upper asymptotic value limits of the share of industrial heat pumps.

1) Current share of heat demand covered by industrial heat pumps

Fig. 2-93 shows the results of estimating the current share covered by industrial heat pumps, based on the assumptions shown in (1).

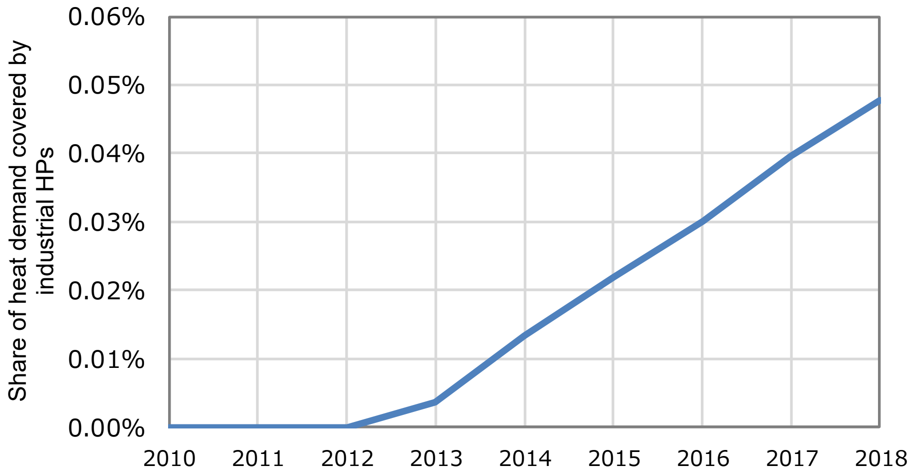


Fig. 2-93 Current share of heat demand covered by industrial HPs at present

2) Upper limit of industrial heat pump introduction by industry and application

In estimating the future share of heat demand covered by industrial heat pumps, three cases, i.e. high, medium, and low cases were assumed regarding the upper asymptotic limit of industrial heat pump introduction (share of heat demand covered by industrial HPs) according to applications. Table 2-45 shows assumptions for factory air conditioning, heating, and low-temperature drying, and Table 2-46 shows assumptions for high temperature use.

For high temperature use, hot air heat pumps and steam-generating heat pumps with a temperature limit of about 120°C have been commercialized, and development of higher temperature technology is under way, but some industries have manufacturing processes with heat zones that cannot be covered by such technologies. Here, the share of industrial heat pumps was assumed to be 0% for four industries: pulp / paper / paper product manufacturing industry, chemical industry, petroleum / coal product manufacturing industry, and iron / steel industry. For industries other than these, the share of industrial heat pumps was assumed to be different, and the upper limit of introduction was set according to the ratio of high-temperature use in the heat demand of each industry.

Table 2-45 Assumption of the upper limit of industrial HP introduction (other than for high temperature use)

Case	Factory air conditioning	Heating	Low temperature drying
High case	Heat demand for factory air conditioning x 80%	Heat demand for low temperature use x 70%	Heat demand for low temperature drying x 70%
Medium case	Heat demand for factory air conditioning x 70%	Heat demand for low temperature use x 50%	Heat demand for low temperature drying x 50%
Low case	Heat demand for factory air conditioning x 60%	Heat demand for low temperature use x 30%	Heat demand for low temperature drying x 30%

Table 2-46 Assumption of the upper limit of industrial HP introduction (for high temperature use)

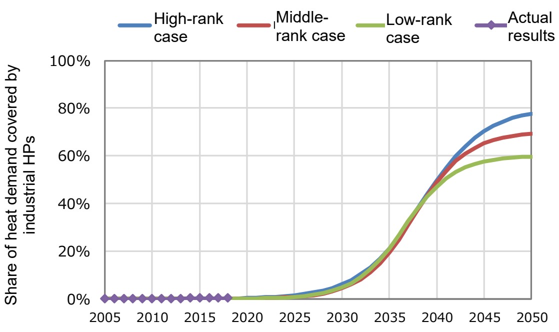
Business type	Ratio of high temperature use to head demand	Upper limit of industrial HP introduction (for high temperature use)		
		High case	Medium case	Low case
Foodstuff manufacturing industry	40%	80%	70%	60%
Beverage / tobacco / feed manufacturing industry	20%	80%	70%	60%
Textile industry	20%	80%	70%	60%
Wood / wood product manufacturing industry (except furniture)	53%	70%	60%	50%
Furniture/ equipment manufacturing industry	53%	70%	60%	50%
Pulp /paper / paper product manufacturing industry	55%	0%	0%	0%
Printing and related industries	53%	70%	60%	50%
Chemical industry	60%	0%	0%	0%
Petroleum / coal products manufacturing industry	80%	0%	0%	0%
Plastic product manufacturing industry (except otherwise classified)	55%	70%	60%	50%
Rubber product manufacturing industry	75%	60%	50%	40%
Tanned leather / leather product / fur manufacturing industry	53%	70%	60%	50%
Ceramic / earth /stone product manufacturing industry	80%	60%	50%	40%
Iron and steel industry	90%	0%	0%	0%
Nonferrous metal manufacturing industry	85%	60%	50%	40%
Metal product manufacturing industry	53%	70%	60%	50%
General-purpose machinery / equipment manufacturing industry	40%	80%	70%	60%
Production machinery / equipment manufacturing industry	40%	80%	70%	60%
Industrial machinery / equipment manufacturing industry	40%	80%	70%	60%
Electronic component / device / circuit manufacturing industry	15%	80%	70%	60%
Electrical machinery /equipment manufacturing industry	15%	80%	70%	60%
Information and communication equipment manufacturing industry	15%	80%	70%	60%
Transportation machinery / equipment manufacturing industry	30%	80%	70%	60%
Other manufacturing industries	53%	70%	60%	50%

For the above assumptions, the upper limit of the industrial heat pump introduction for each application in each case can be organized as shown in Table 2-47 by taking a weighted average for the heat demand by industry shown in Table 2-44.

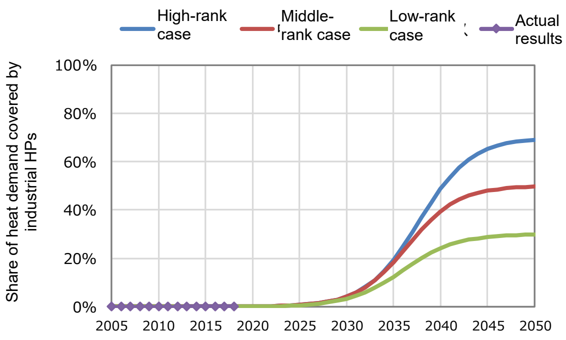
Table 2-47Assumption of the upper limit of agricultural HP introduction

Case	Factory air conditioning	Heating	Low temperature drying	High temperature
High case	80%	70%	70%	19%
Medium case	70%	50%	50%	17%
Low case	60%	30%	30%	14%

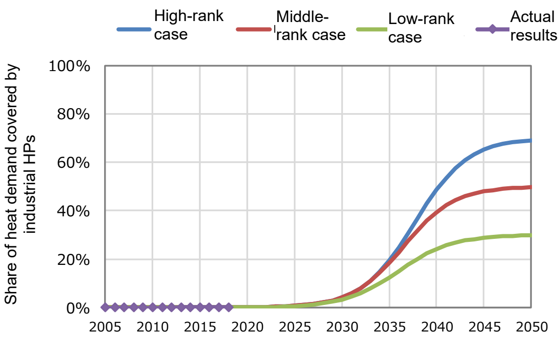
For the forecast of future trends toward the upper limit on the introduction of the share of heat demand covered by industrial heat pumps in the industrial heating market, logistic regression to the current trends if shares was applied for setting. Since the hurdle for replacing existing equipment was considered higher for industrial heat pumps than other applications, it was assumed that the above-mentioned upper limit of introduction will be almost reached around FY2065, which is approximately four cycles of product life. Fig. 2-94 shows the estimation results of the future share of heat demand covered by industrial heat pumps in the industrial heating market, which was estimated for the high, medium, and low cases.



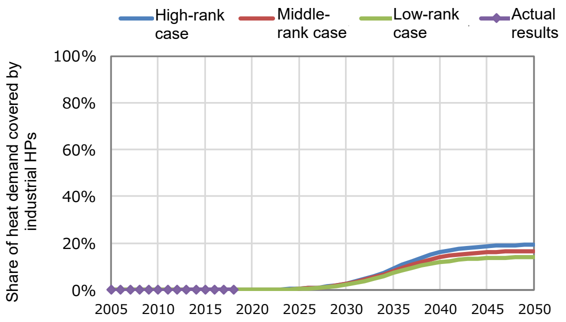
Factory air conditioning



Heating



Low temperature drying



High temperature

Fig. 2-94 Estimation of the future share of heat demand covered by industrial HPs in the industrial heating market

(3) Flow efficiency of industrial heating equipment

The flow efficiency of industrial heating equipment by type was set as shown in Fig. 2-95.

The efficiency of industrial heat pumps was set based on the results of HPTCJ's survey on the efficiency of industrial heat pumps currently on the market, trend of technological development, etc.

For industrial boilers, the boiler efficiency was assumed to be constant at 0.9 for factory air conditioning, hot water supply, and drying. For high temperature use, 20% of steam piping loss was further expected and the total efficiency of boiler was assumed to be constant at 0.72 (= 0.9 x 0.8).

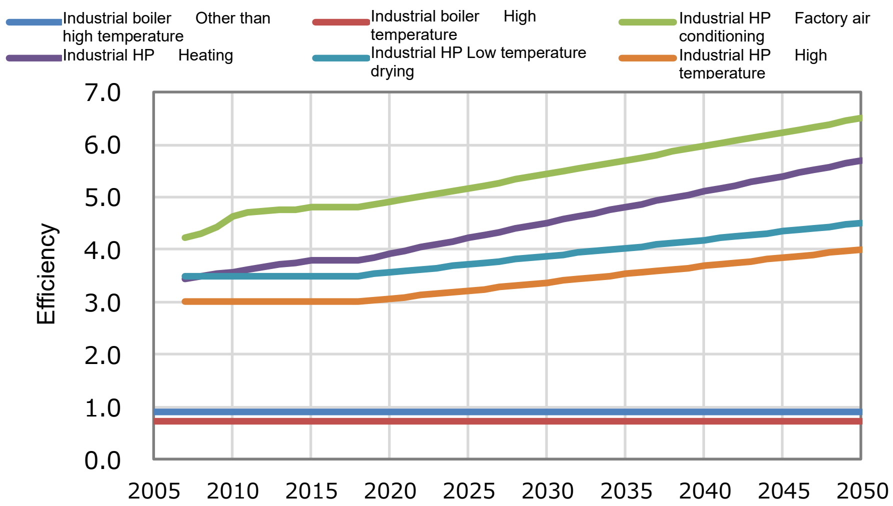


Fig. 2-95 Assumption of flow efficiency of industrial heating equipment by type

2.6.4 Calculation results

(1) Shipping capacity / stock capacity

The estimation results of the shipping capacity and stock capacity of industrial heat pumps based on the assumptions above are shown in Fig. 2-96 and Fig. 2-97, respectively.

Shipping capacity is expected to grow rapidly until after FY2035, then decline until around FY2045, and then expand again before shrinking. This is considered to represent the accelerated introduction of boilers into the market where the economic advantage over industrial boilers works and a subsequent drop-off when the market is saturated. After FY2045, the increase or decrease is considered to be repeated according to the demand, etc. for renewal of industrial heat pumps introduced.

In either case, the stock capacity is expected to almost reach the upper limit of introduction by around FY2045.

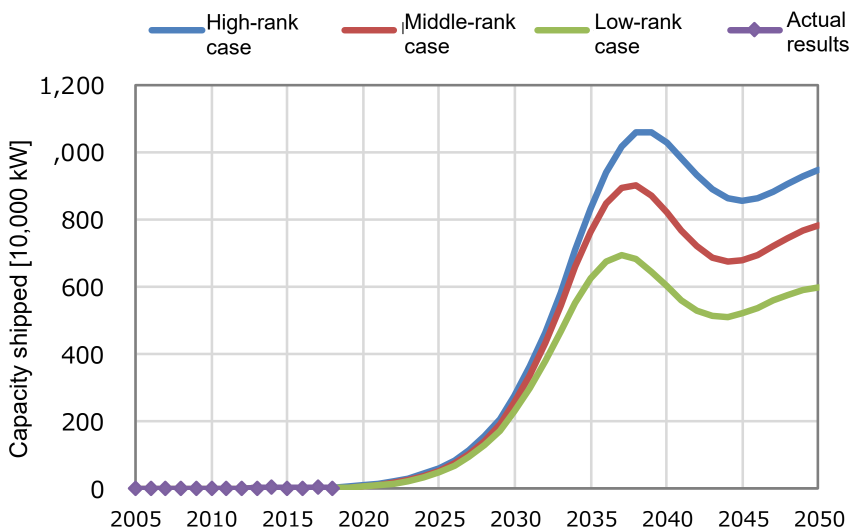


Fig. 2-96 Estimation results of the shipping capacity of industrial HPs

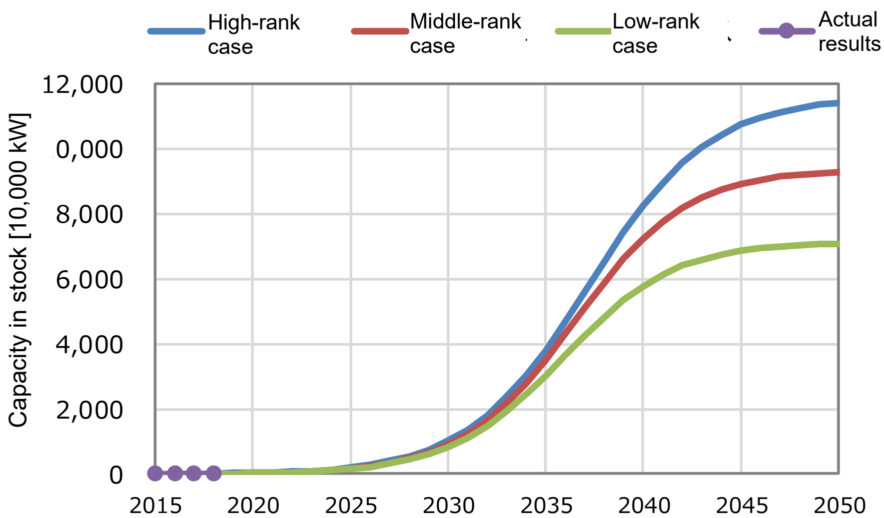
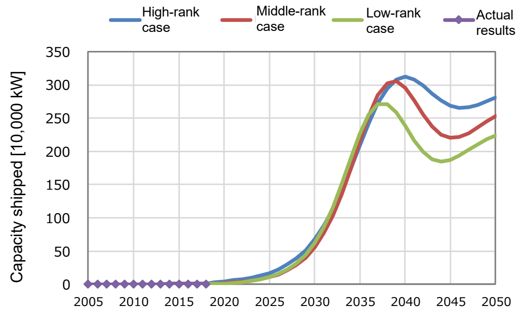


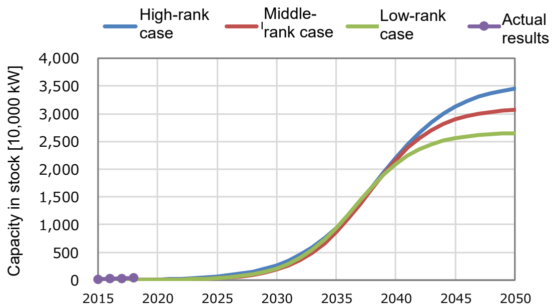
Fig. 2-97 Estimation results of the estimation for the stock capacity of industrial HPs

(Reference) Shipping capacity and stock capacity for each application

For reference, Fig. 2-98 shows the estimation results of the shipping capacity and stock capacity of industrial heat pumps for each application in the high, medium, and low cases, respectively.

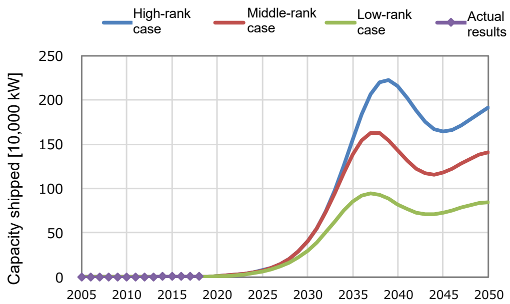


Shipping capacity

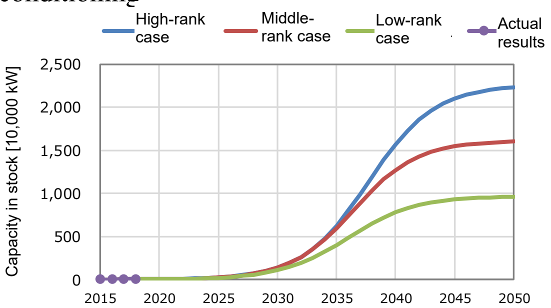


Stock capacity

For factory air conditioning

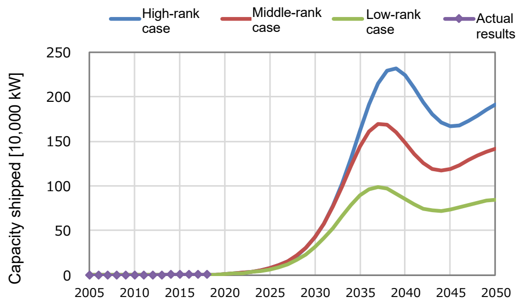


Shipping capacity

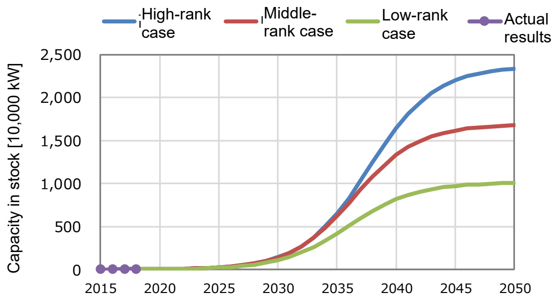


Stock capacity

For heating

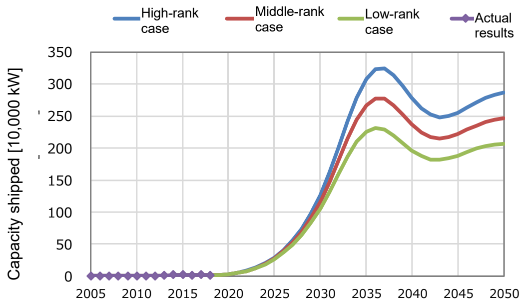


Shipping capacity

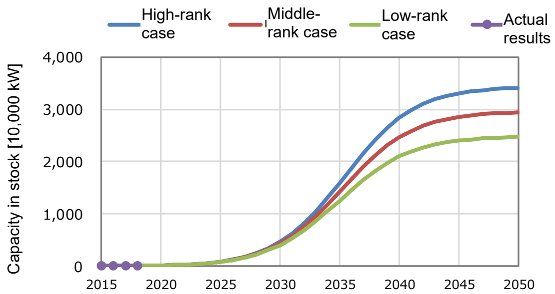


Stock capacity

For low temperature drying



Shipping capacity



Stock capacity

For high temperature use

Fig. 2-98 Estimation results of the shipping and stock capacity of industrial HPs by application

(2) Primary energy consumption, energy saving effect, CO2 reduction effect

Fig. 2-99 shows the calculation results of the primary energy consumption based on the estimation results of shipping capacity and stock capacity above, and the assumed flow efficiency, full load equivalent operating time, and primary energy conversion factor for electricity.

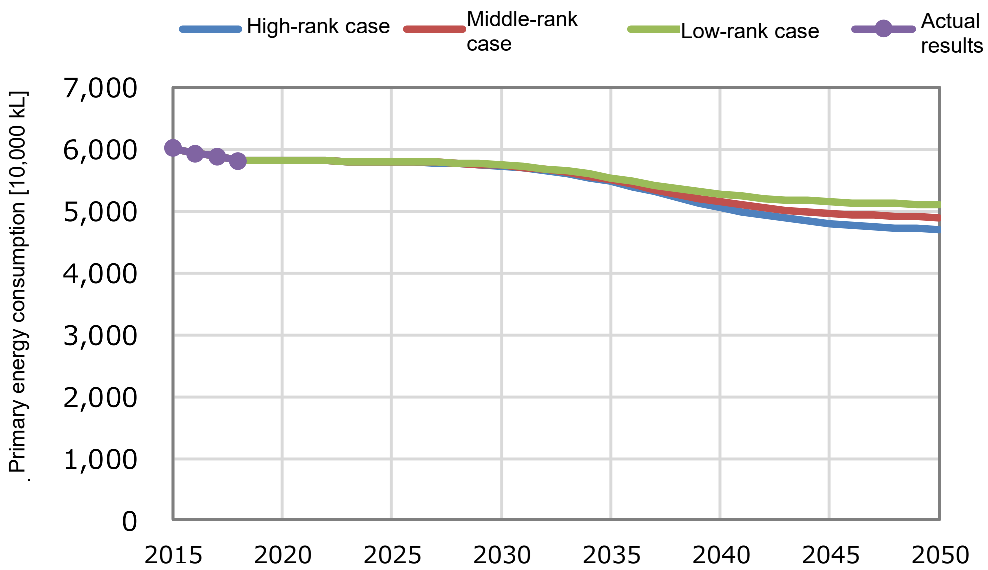


Fig. 2-99 Estimation results of primary energy consumption: Industrial heating

Based on the results above, Table 2-48 shows the energy-saving effect (effect of reduction in primary energy consumption) from the fixed status case for each case, assuming that the current (FY2018) stock share and flow efficiency of industrial heat pumps will remain constant in the future.

The energy savings in the medium case for the FY2050 cross section is estimated to be 9.13 million kL/year, of which the replacement effect of industrial boilers is estimated to be 6.74 million kL/year and the efficiency improvement effect of industrial heat pumps is estimated to be 2.39 million kL/year.

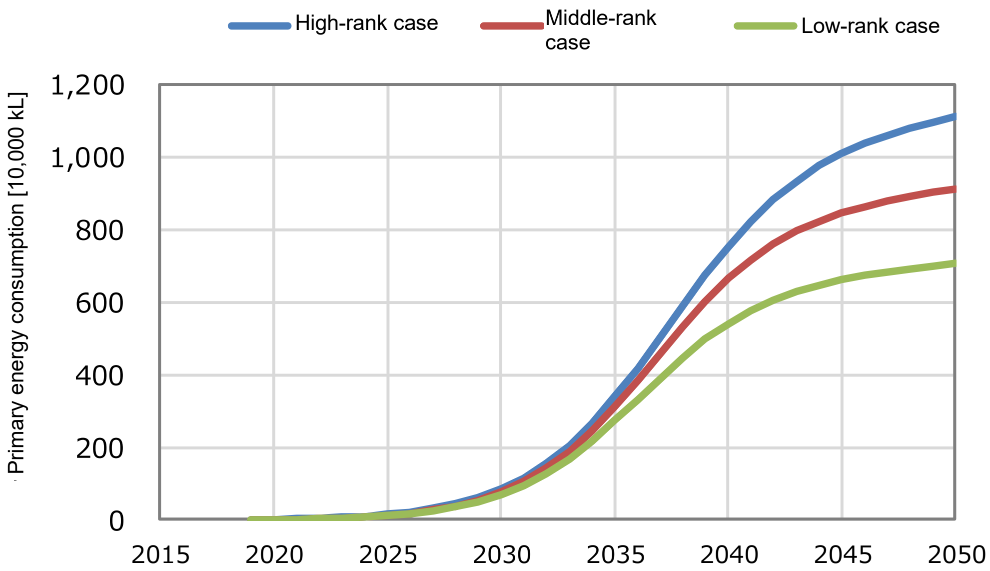


Fig. 2-100 Estimation results of energy saving effect: Industrial heating

Table 2-48 Breakdown of energy saving effect: Industrial heating

Case	Breakdown		Energy saving effect (10,000 kL/year)			
			FY2020	FY2030	FY2040	FY2050
High case	Total		1	85	754	1,112
		Replacement effect of industrial boilers	1	74	592	816
		Efficiency improvement effect of industrial HPs	0	12	162	296
Medium case	Total		1	75	665	913
		Replacement effect of industrial boilers	1	65	525	674
		Efficiency improvement effect of industrial HPs	0	11	140	239
Low case	Total		1	70	541	708
		Replacement effect of industrial boilers	1	60	432	528
		Efficiency improvement effect of industrial HP	0	10	109	180

Note: Due to rounding, the sum of each value does not necessarily equal the total value shown.

Table 2-49 shows the CO_2 reduction effect estimated by multiplying the above energy saving effect by CO_2 intensity. Note that there are a wide variety of fuel types used in industrial boilers, which are represented by major fuel types, i.e., heavy oil A, city gas, and LPG, in this document for the sake of convenience, and the weighted average was calculated using the input by fuel type for private steam generation in the manufacturing industry specified in the General Energy Statistics.

The CO_2 reduction effect in the medium case for the FY2050 cross section is estimated to be 33.54 million t-CO_2/year, of which the replacement effect of industrial boilers is estimated to be 32.4 million t-CO_2/year and the efficiency improvement effect of industrial heat pumps is estimated to be 1.14 million t-CO_2/year.

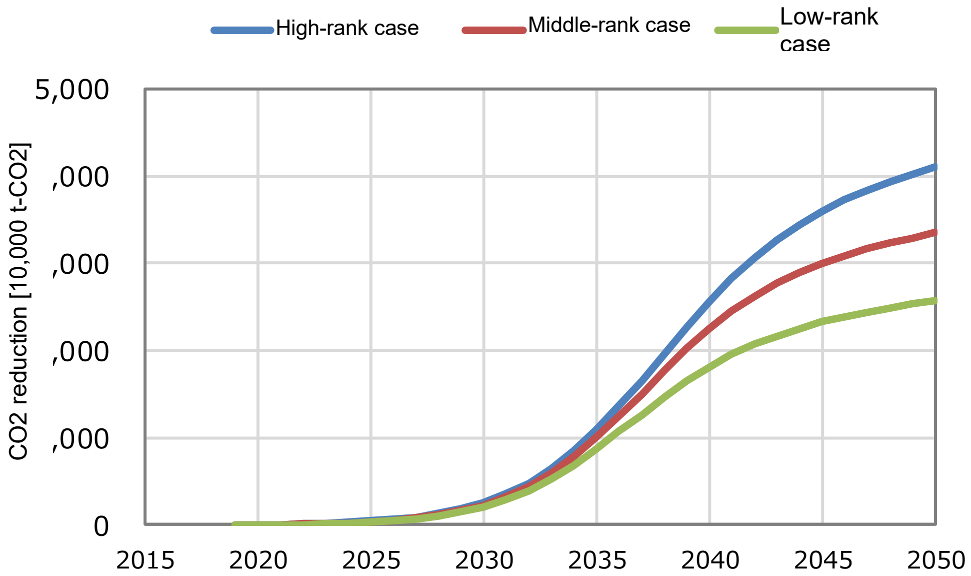


Fig. 2-101 Estimation results of CO_2 reduction effect: Industrial heating

Table 2-49 Breakdown of the CO_2 reduction effect: Industrial heating

Case	Breakdown		CO2 reduction effect (10,000 t-CO2/year)			
			FY2020	FY2030	FY2040	FY2050
High case	Total		3	256	2,562	4,104
		Replacement effect of industrial boilers	3	238	2,404	3,963
		Efficiency improvement effect of industrial HPs	0	17	158	141
Medium case	Total		2	228	2,250	3,354
		Replacement effect of industrial boilers	2	212	2,113	3,240
		Efficiency improvement effect of industrial HPs	0	16	136	114
Low case	Total		2	209	1,812	2,579
		Replacement effect of industrial boilers	2	195	1,706	2,493
		Efficiency improvement effect of industrial HPs	0	14	106	86

Note: Due to rounding, the sum of each value does not necessarily equal the total value shown.

2.7 Agricultural use

2.7.1 Preconditions

In the greenhouse horticulture sector, agricultural boilers and agricultural heat pumps are used to heat greenhouses. At present, agricultural boilers fueled by heavy oil are used in many cases. By converting these to agricultural heat pumps, significant energy saving effect can be expected.

Therefore, for agricultural use, the energy saving effects expected of replacing heavy oil-fired agricultural boilers with agricultural heat pumps for greenhouse horticulture were evaluated.

2.7.2 Calculation flow

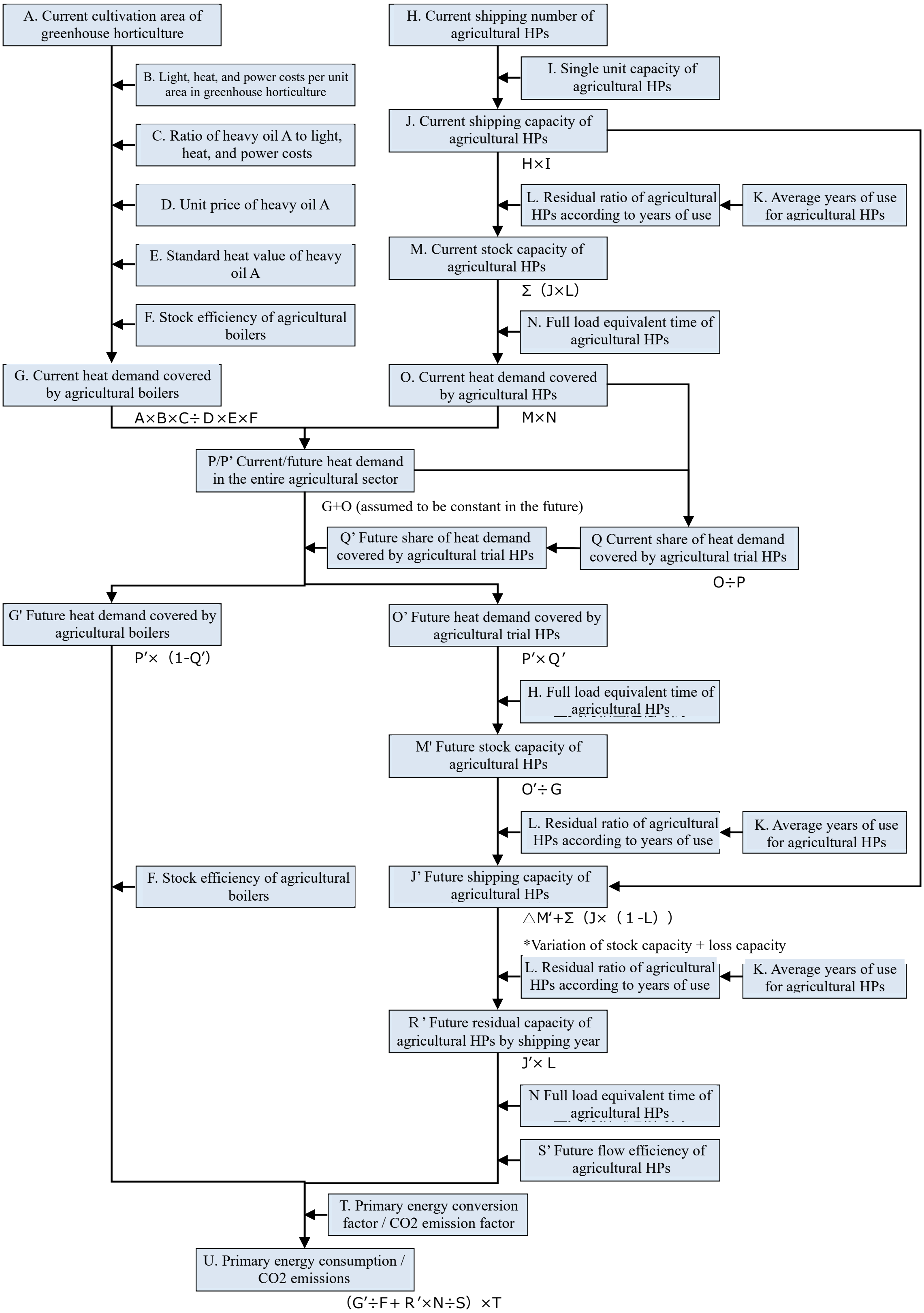


Fig. 2-102 Calculation flow of the diffusion forecast of agricultural HPs in the agricultural market

2.7.3 Data used for calculation

(1) Market size of agricultural heating equipment (heat demand in the agricultural sector)

The heat demand in agriculture (greenhouse horticulture) was estimated separately for the portion covered by agricultural boilers (heavy oil A) and for the portion covered by agricultural heat pumps.

1) Heat demand currently covered by agricultural boilers (heavy oil A)

Heat demand covered by agricultural boilers (heavy oil A) was estimated as shown in Table 2-50.

Table 2-50 Estimation method of heat demand covered by agricultural boilers (heavy oil A) in greenhouse horticulture

Used data	Vegetables	Flowers	Source / Calculation method
(1) Cultivation area of greenhouse horticulture	424,890,000sand m2	71,174,000 m2	From "Installation etc. of Horticultural Facilities (2008)," MAFF
(2) Light, heat, and power costs per unit area in greenhouse horticulture	245 yen/m2	473 yen/m2	Based on the MAFF' Agricultural Management Statistics Survey (2008), the light, heat, and power costs per area was estimated for both individual management (single management) and organizational management, and weighted average was calculated with the ratio of cultivated area between individual management and organizational management in the 2015 Agriculture and Forestry Census results.
(3) Of the light, heat, and power costs Ratio of heavy oil A	30%	30%	Set based on the annual price indexes of agricultural production materials for 2011-2015 in the Agricultural Price Statistics by the MAFF.
(4) Unit price of heavy oil A	83 yen/L	83 yen/L	National average price of "Small Lorry Price" for "Industrial Price (Light Oil / Heavy Oil A)"for the period from April 2018 to March 2019 in the Agency for Natural Resources and Energy's "Petroleum Product Price Survey"
(5) Standard heat value of heavy oil A	38.9 MJ/L	38.9 MJ/L	From "2018 Standard Heat Value List" by Energy Source" Agency for Natural Resources and Energy,
(6) Boiler efficiency	0.9	0.9	Assumed value
(7) Heat demand covered by agricultural boilers	3,676 million kWh	1,189 million kWh	Calculated as 1) x 2) x 3) / 4) x 5) x 6) x 0.278 kWh/MJ
Total	4,865 million kWh		

2) Heat demand currently covered by agricultural heat pumps

The heat demand covered by agricultural heat pumps was estimated by multiplying the number of heat pumps in stock, which was obtained by considering the residual rate for the current number of agricultural heat pumps shipped, and then multiplying the above number in stock by the capacity of a single unit and the operation time equivalent to the full load.

a. Current shipping number of agricultural heat pumps

Since no data that systematically organizes the shipping number of agricultural heat pumps was found, the shipping number of agricultural heat pumps was estimated by combining several references. Table 2-51 shows the method of estimating the shipping number of units in each fiscal year.

Table 2-51 Method of estimating the shipping number of agricultural heat pumps

Target year of estimation	Source / Calculation method
(1) FY2007-FY2050	Refer to "Technological Risk Management in Production Sites for Establishing Sustainable Production Areas," Agriculture and Environment Adaption Division, Production Bureau, MAFF (Aug. 2016).
(2) FY2015	Refer to "Energy-saving Equipment Introduction in FY2015" by Japan Greenhouse Horticulture Association.
(3) FY2016-FY2018	(1) Heating area per unit (ha) was estimated by dividing the incremental area heated by heat pumps, which can be obtained from the "Installation of Greenhouse Horticultural Facilities (2018)" of the MAFF by the number of units shipped in (1) and (2). (2) The total number of units shipped in FY2017 and FY2018 was calculated by dividing the incremental area heated by heat pumps from FY2016 to FY2018 by the area heated per unit calculated in (1). The number of units shipped in FY2017 and FY2018 was calculated by assuming that the ratio of units shipped in FY 2017 and FY 2018 is the same. . (3) Since the number of units shipped in FY2016 cannot be estimated correctly by the method in (2) due to the impact of the "Emergency measures for fuel price hikes," the average values for FY2015 and FY2017 are used.

Fig. 2-103 shows the trends in the shipping number of agricultural heat pumps estimated by the method above. Since FY2012, the Ministry of Agriculture, Forestry and Fisheries ("MAFF") has implemented "Emergency Measures for Fuel Oil Price Hikes" in response to the sharp rise in the price of heavy oil A, and shipments of agricultural heat pumps have increased significantly. However, as the price of fuel oil A has been falling since FY2015, the growth in shipments of agricultural heat pumps are expected to settle down for the time being.

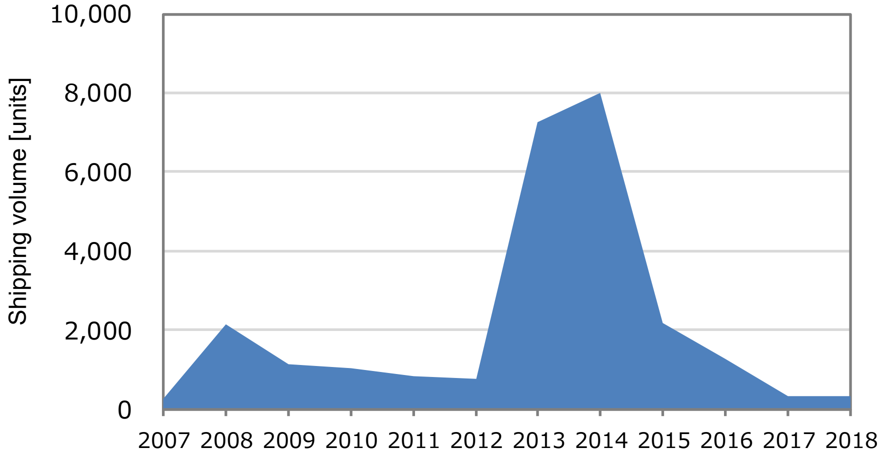


Fig. 2-103 Trends in the current shipping number of agricultural HPs

b. Single unit capacity of agricultural heat pumps

Since most of agricultural heat pumps currently on the market have a lineup of capacities ranging from 4 horsepower (11.2 kW) to 10 horsepower (28.0 kW) according to the catalogs of the manufacturers, the single unit capacity of agricultural heat pumps was set at the intermediate value of 19.6 kW ((11.2 + 28.0) / 2).

c. Average years of use, residual curves

Although the legal useful life of agricultural equipment is specified to be 7 years, the average useful life was set at 10 years, considering the fact that the equipment is actually used beyond the legal useful life in many cases.

The residual curve (residual rate by years of use) is expressed by the following equation Parameters α and β, which represent the shape of residual curves, need to be set so that the average service life of agricultural heat pumps estimated from the residual curve is consistent with the assumption of the average service life described above.

$$\text{Residual ratio} = e^{-\alpha(\text{elapsed years} \quad \beta)}$$

Fig. 2-104 shows the residual curve set as described above.

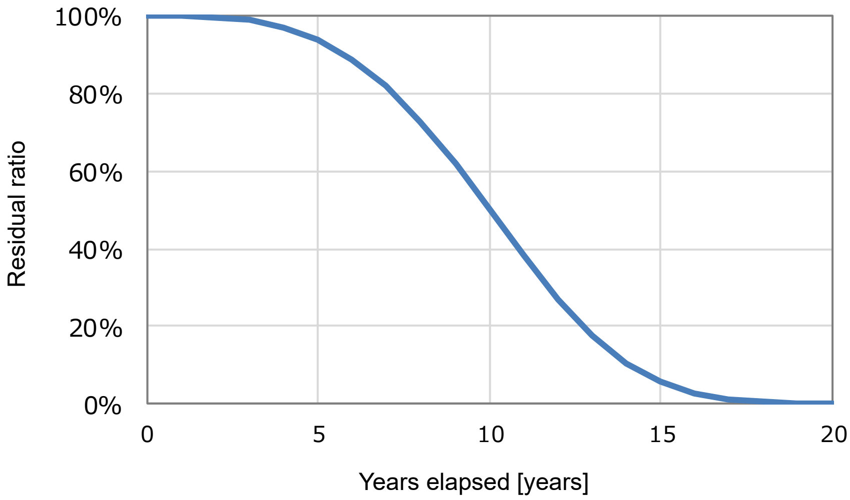


Fig. 2-104 Residual ratio of agricultural HP

d. Operating time of agricultural HP equivalent to the full load.

The full load equivalent operating time of agricultural heat pumps was assumed to be 1,700h/year, referring to the actual operation results, etc. specified in the existing literature, etc. (Association for Agricultural Electrification, "Effective Use of Heat Pump in Greenhouse Horticulture -Energy Saving and Multi-faceted Use-").

e. Heat demand covered by agricultural heat pumps

Based on the assumptions above, the estimated heat demand covered by agricultural heat pumps in the current fiscal year (FY2018) was 753 million kWh.

3) Heat demand in the agricultural sector

Based on the above, the current heat demand (FY2018) in the entire agricultural sector (greenhouse horticulture) was estimated to be 5,618 million kWh, as shown in Table 2-52.

As for the future, the present (FY2018) level was assumed to remain.

Table 2-52 Heat demand in the agricultural sector

		Heat demand	Share
Entire agricultural sector		5,618million kWh	100%
	Portion covered by agricultural boilers	4,865 million kWh	87%
	Portion covered by agricultural HPs	753 million kWh	13%

(2) Share of heat demand covered by agricultural heat pumps

The share of heat demand covered by agricultural heat pumps in the agricultural sector was set by applying logistic regression to the transition of the current share of heat demand covered by agricultural heat pumps shown in (1).

However, as stated above, although the current share has been expanding rapidly due to the sharp rise in the price of heavy oil A and the effect of accompanying support measures, etc. for agricultural heat pumps, it was assumed that this expansion would tend to settle down for the present as the price of heavy oil A has been falling since FY2015.

In applying the logistic regression, as shown in Table 2-53, three cases of high, medium, and low were assumed as the upper asymptote of the share of agricultural heat pumps. It was also assumed that the upper asymptote would be almost reached around FY2050, which is roughly three product life cycles away.

Table 2-53 Assumption of the upper limit of agricultural HP introduction

Case	Upper limit of agricultural HP introduction (upper limit of the share of heat demand covered by agricultural HPs)
High case	Heat demand in the agricultural sector x 90%
Medium case	Heat demand in the agricultural sector x 60%
Low case	Heat demand in the agricultural sector x 40%

Based on the assumptions above, Fig. 2-105 shows the estimation results of the share of heat demand covered by agricultural heat pumps in each of the high, medium, and low cases.

As of FY2050, the introduction limit has not yet been reached, and it is expected to continue to grow after FY2050.

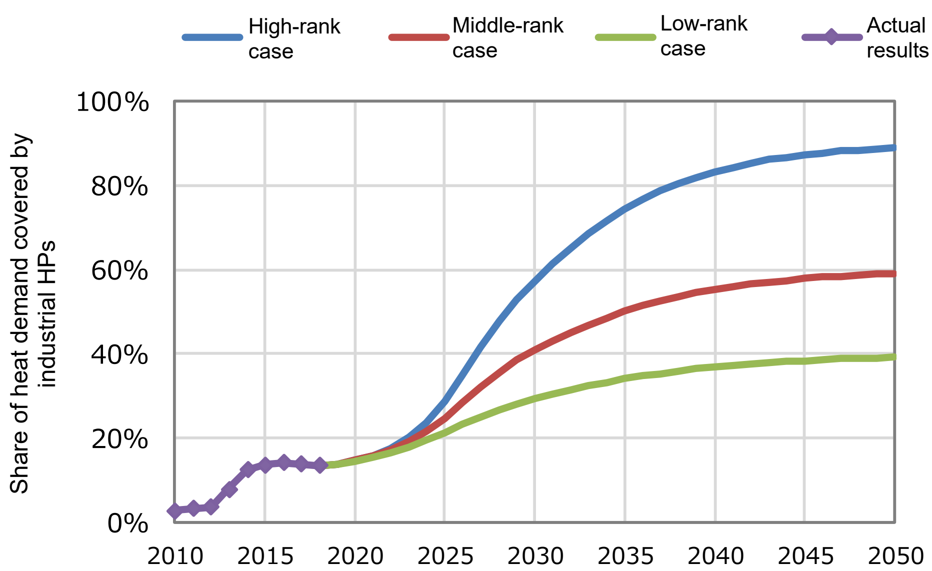


Fig. 2-105 Assumption of the share of heat demand covered by industrial HPs in the future

(3) Flow efficiencies of agricultural boilers and heat pumps

The flow efficiencies of agricultural boilers and agricultural heat pumps were set as shown in Fig. 2-106.

The efficiency of agricultural heat pump was assumed to be the same as that of industrial packaged air conditioners.

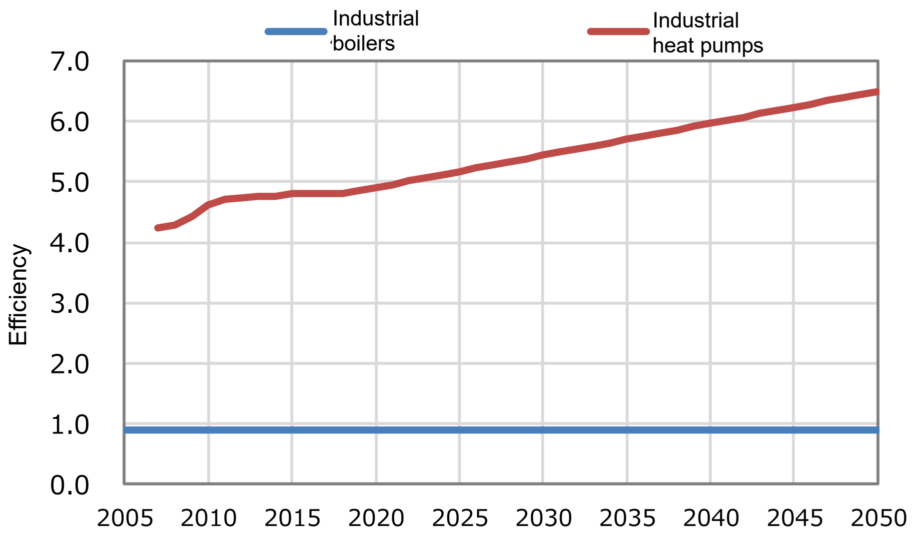


Fig. 2-106 Assumption of flow efficiency for agricultural boilers and HPs

Note: Figure provides the efficiencies of agricultural heat pumps since 2007, in which they became commercially available.

2.7.4 Calculation results

(1) Shipping capacity / stock capacity

The estimation results of the shipping capacity and stock capacity of agricultural heat pumps based on the assumptions above are shown in Fig. 2-107 and Fig. 2-108, respectively.

Shipping capacity and stock capacity of agricultural heat pumps will both grow significantly, with shipping capacity reaching approximately 190MW and stock capacity approximately 1.95MW in the medium case for the FY2050 cross section. Although the rate of growth will slow down, it is expected to continue to expand after FY2050.

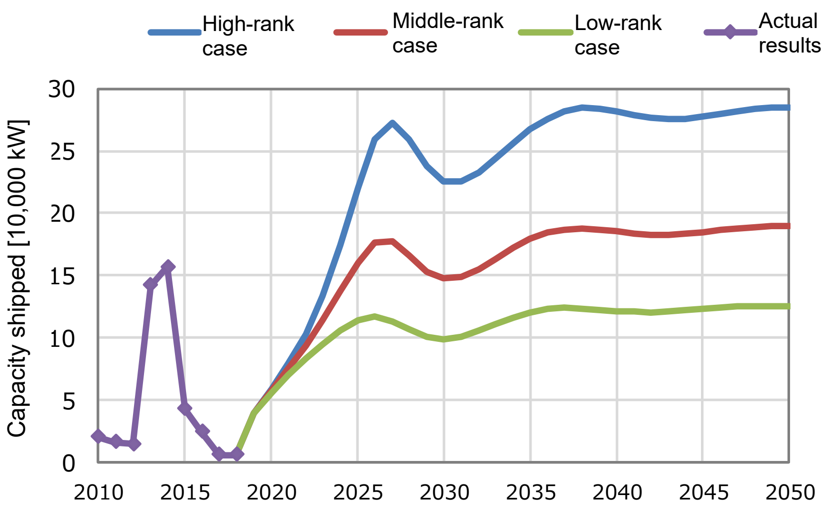


Fig. 2-107 Estimation results of the shipping capacity of agricultural HPs: Agricultural use

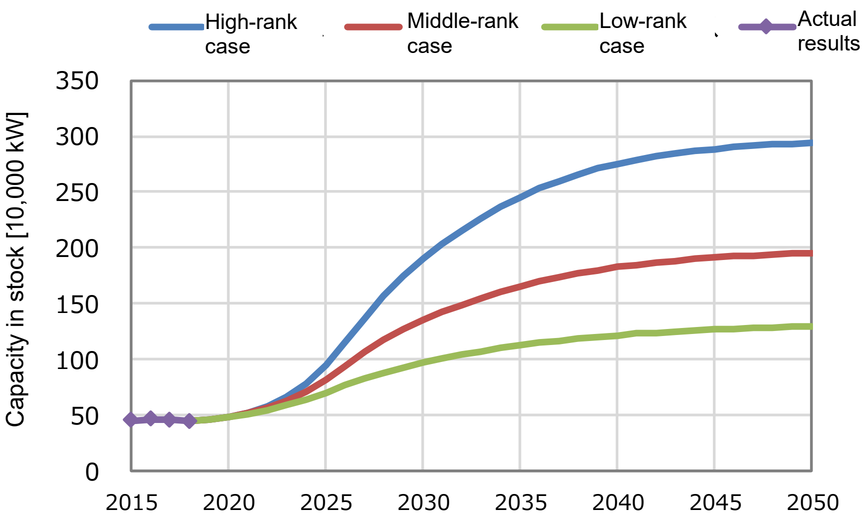


Fig. 2-108 Estimation results of the stock capacity of agricultural HPs: Agricultural use

(2) Primary energy consumption, energy saving effect, CO_2 reduction effect

Fig. 2-109 shows the calculation results of the primary energy consumption based on the estimation results of shipping capacity and stock capacity above, and the assumed flow efficiency, full load equivalent operating time, and primary energy conversion factor for electricity.

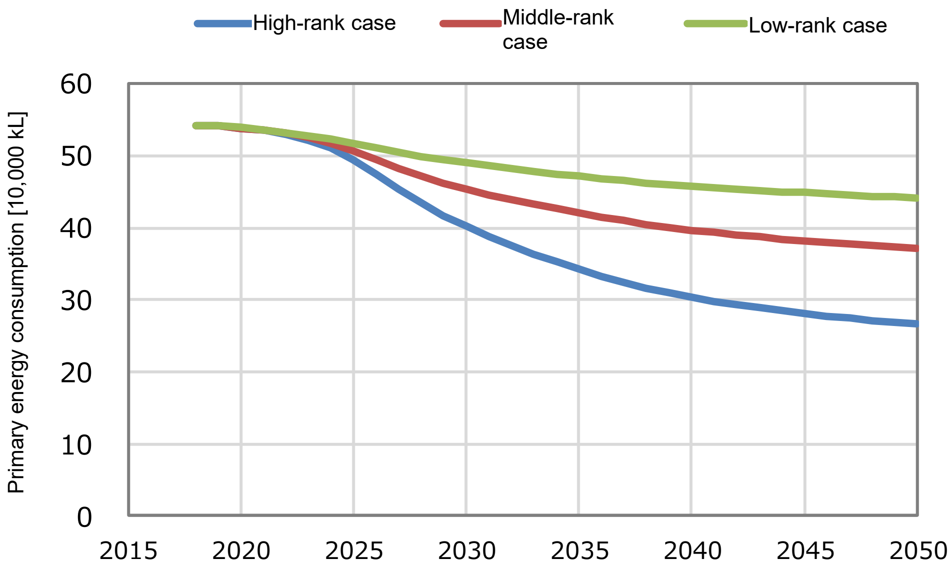


Fig. 2-109 Estimation results of primary energy consumption: Agricultural use

Based on the results above, Fig. 2-110 and Fig. 2-54 show the energy-saving effect (effect of reduction in primary energy consumption) from the fixed status case for each case, assuming that the current (FY2018) stock share and flow efficiency of agricultural heat pumps will remain constant in the future.

The energy savings in the medium case for the FY2050 cross section is estimated to be 170,000 kL/year, of which the replacement effect of agricultural boilers is estimated to be 130,000 kL/year and the efficiency improvement effect of agricultural heat pumps is estimated to be 40,000 kL/year.

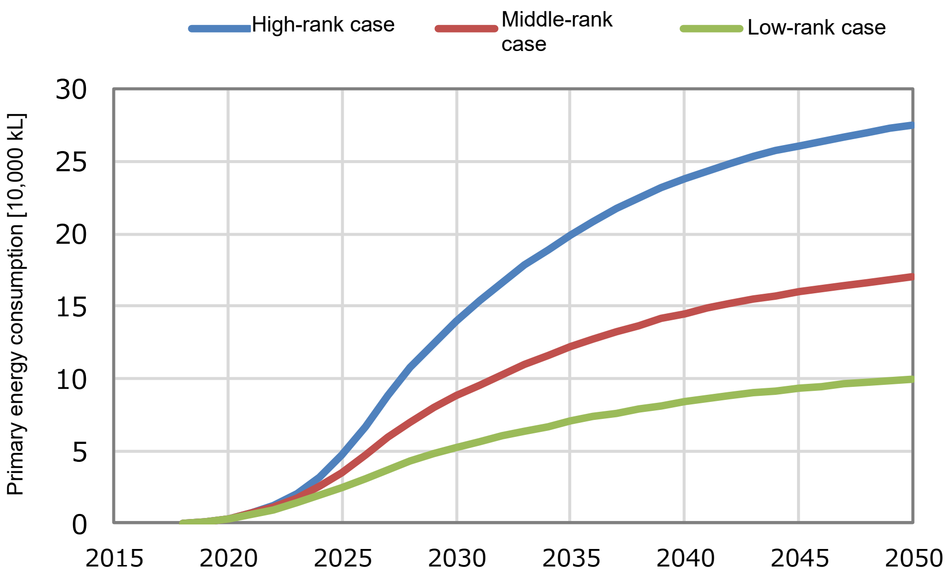


Fig. 2-110 Estimation results of energy saving effect: Agricultural use

Table 2-54 Breakdown of energy saving effect: Agricultural use

Case	Breakdown		Energy saving effect (10,000 kL/year)			
			FY2020	FY2030	FY2040	FY2050
High case	Total		0	14	24	28
		Replacement effect of agricultural boilers	0	13	20	22
		Efficiency improvement effect of agricultural HPs	0	1	4	6
Medium case	Total		0	9	14	17
		Replacement effect of agricultural boilers	0	8	12	13
		Efficiency improvement effect of agricultural HPs	0	1	3	4
Low case	Total		0	5	8	10
		Replacement effect of agricultural boilers	0	5	7	7
		Efficiency improvement effect of agricultural HPs	0	1	2	3

Note: Due to rounding, the sum of each value does not necessarily equal the total value shown.

Fig. 2-111 and Table 2-55 show the CO2 reduction effect estimated by multiplying the above energy saving effect by CO2 intensity.

The CO2 reduction effect in the medium case for the FY2050 cross section is estimated to be 670,000 t-CO2/year, of which the replacement effect of agricultural boilers is estimated to be 650,000 t-CO2/year and the efficiency improvement effect of industrial heat pumps is estimated to be 20,000 t-CO2/year.

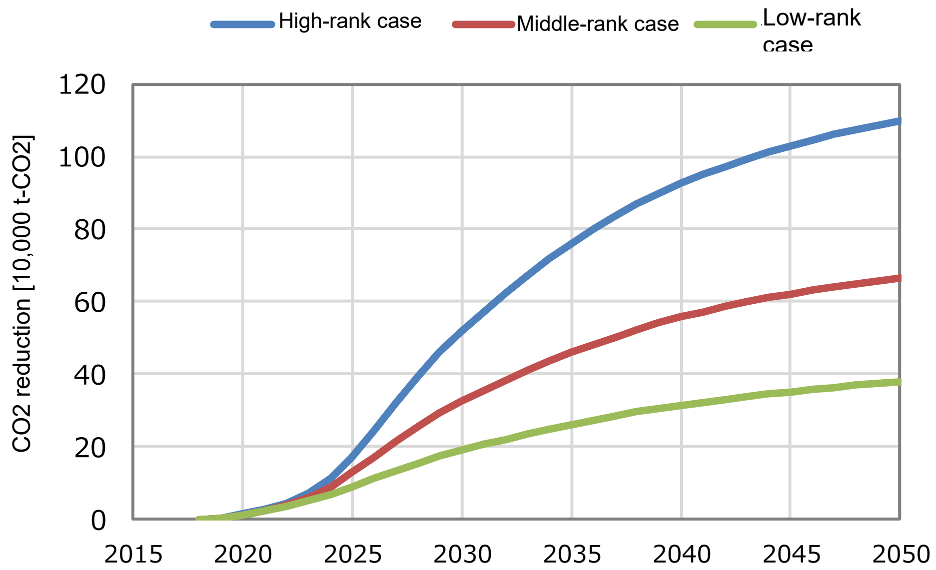


Fig. 2-111 Estimation results of CO2 reduction effect: Agricultural use

Table 2-55 Breakdown of the CO2 reduction effect: Agricultural use

Case	Breakdown	CO2 reduction effect (10,000 t-CO2)			
		FY2020	FY2030	FY2040	FY2050
High case	Total	1	52	93	110
	Replacement effect of agricultural boilers	1	50	89	107
	Efficiency improvement effect of agricultural HPs	0	2	4	3
Medium case	Total	1	32	56	67
	Replacement effect of agricultural boilers	1	31	53	65
	Efficiency improvement effect of agricultural HPs	0	1	2	2
Low case	Total	1	19	31	38
	Replacement effect of agricultural boilers	1	18	30	37
	Efficiency improvement effect of agricultural HPs	0	1	2	1

Note: Due to rounding, the sum of each value does not necessarily equal the total value shown.

2.8 Use for snow melting

2.8.1 Preconditions

(1) Equipment to be evaluated

There are various types of areas where snow-melting is performed, such as roads, roofs, and general demand areas (e.g., store parking lots). This research focused on road heating on the roads (national, prefectural, and municipal roads), where the availability of quantitative data necessary for estimating the diffusion forecast is relatively high.

The heat source equipment for road heating can be broadly classified into three types: heat pump, electric heating, and hot water (gas-fired boiler, oil (kerosene) fired boiler). At present, electric heating and hot water types account for most of the market, and heat pump type is hardly widespread.

Therefore, for snow-melting, the effect of replacing electric heating and hot water types with heat pumps for snow-melting was evaluated.

(2) Establishing market segment

Three heavy snowfall regions, Hokkaido, Tohoku, and Hokuriku, were chosen as target regions.

Since the climate (amount of snowfall, outside temperature, etc.) differs according to these regions and the type of road heating (shares of electric heating type, hot water type, etc.) adopted is also expected to differ according to the climate, the diffusion forecast was estimated according to the division of these regions.

Table 2-56 Regional classification

Regional classification	Applicable prefecture
Hokkaido	Hokkaido
Tohoku	Aomori-ken, Iwate-ken, Miyagi-ken, Akita-ken, Yamagata-ken, Fukushima-ken
Hokuriku	Niigata-ken, Toyama-ken, Ishikawa-ken, Fukui-ken

2.8.2 Calculation flow

Fig. 2-112 shows the calculation flow of the diffusion forecast of heat pumps for snow-melting in the snow-melting equipment market.

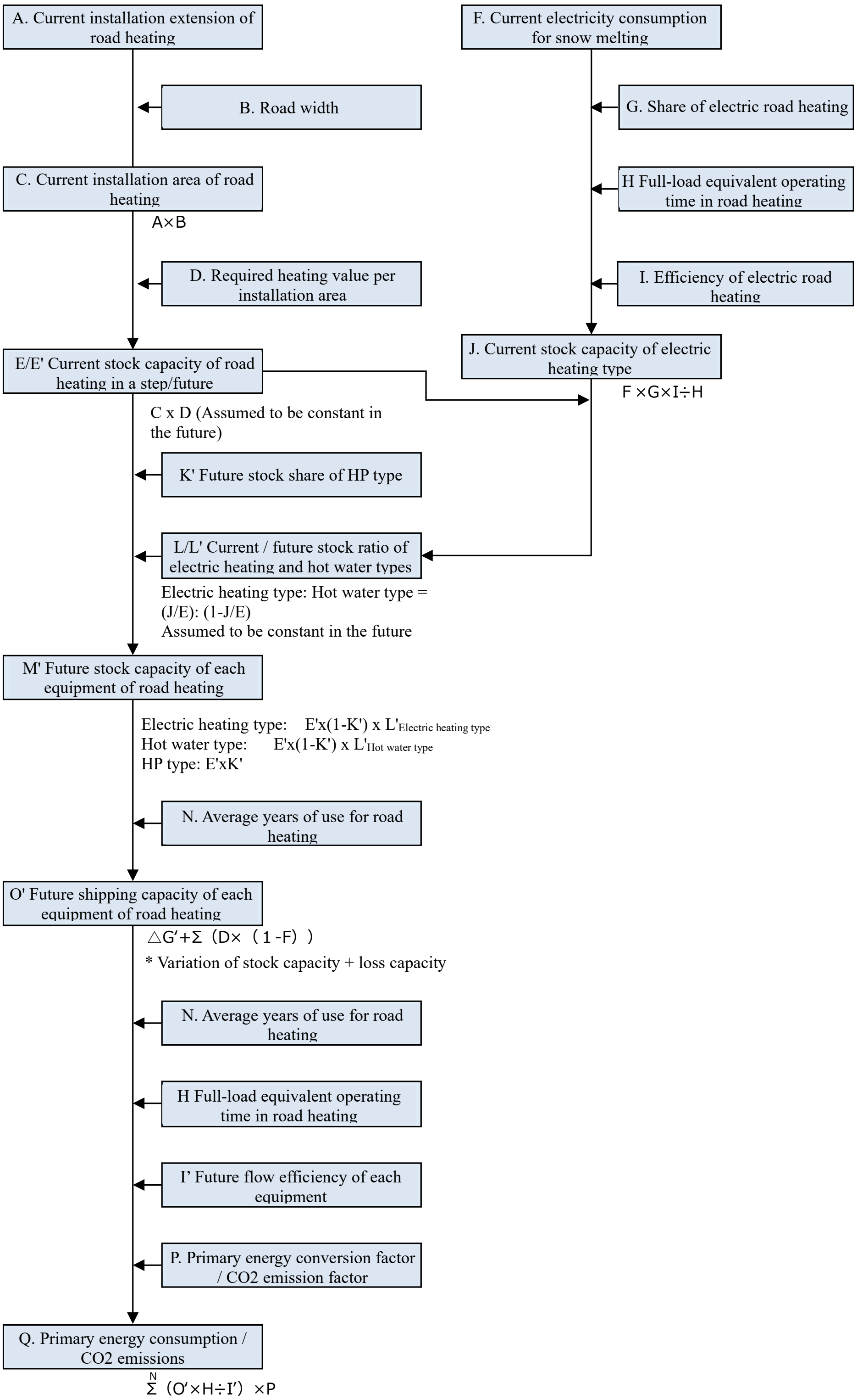


Fig. 2-112 Calculation flow of the diffusion forecast of heat pumps for snow-melting in the snow-melting equipment market

2.8.3 Data used for calculation

(1) Market size of snow melting equipment (stock capacity of road heating)

The current market size of snow-melting equipment (stock capacity of road heating) was estimated by multiplying the installation area of road heating by the required heating value per installation area. As for the future, the present (FY2018) level was assumed to remain.

The shipping capacity was estimated by dividing the stock capacity by the average years of use.

1) Installation area of road heating by region

As for the actual value of the installation area of road heating by region at present (FY2018), as shown in Table 2-57, it was estimated by multiplying the installation extension of road heating according to each prefecture and road type (national, prefectural, and municipal roads) by the road width according to each prefecture and road type (national, prefectural, and municipal roads), and then aggregating the results according to each region.

Table 2-57 Method of estimating the installation area of road heating by region

Used data		Source / Calculation method
(1)	Extension of road heating installation	MLIT "Study on Analysis of Current Conditions in Heavy Snowfall Areas (Basic Data)"
(2)	Road width	Calculated by dividing the "road area (road section)" in the MLIT's "Road Statistics Annual Report " by the "actual road extension.
(3)	Road heating installation area	Estimated as (1) x (2)

Table 2-58 shows the estimation results of the current installation area of road heating by region. It was assumed that this current installation area would remain constant in the future.

Table 2-58 Estimation results of the current installation area of road heating by region

		Road heating Installation extension[km]	Road width (weighted average of national, prefectural and municipal roads) [m].	Road heating Installation area [10,000 m2]
Hokkaido		214	7.8	167
Tohoku		290	6.3	183
	Aomori-ken	35	6.4	23
	Iwate-ken	48	5.9	28
	Miyagi-ken	12	6.3	7
	Akita-ken	98	6.1	60
	Yamagata-ken	66	7.2	47
	Fukushima-ken	31	5.7	18
Hokuriku		64	6.9	44
	Niigata-ken	16	6.2	10
	Toyama-ken	18	7.2	13
	Ishikawa-ken	23	7.3	16
	Fukui-ken	7	6.7	5

2) Required heating value per installation area by region

For the required heating value per installation area of road heating, standard values are provided by the "Guidelines for the Design of Road Heating Equipment" (Association of Electricity and Telecommunication Engineering for Land and Infrastructure).

Based on the Guidelines, the value for Hokkaido (Central region) was set at 250 W/m2, and 200 W/m2 for Tohoku and Hokuriku.

Table 2-59 Required heating value per installation area of road heating equipment

Region	Required heat generation
Hokkaido (East Hokkaido / North Hokkaido)	300 W/m2
Hokkaido (Central region), Tohoku (mountainous area)	250 W/m2
Hokkaido (South region), Tohoku, Hokuriku	200 Wm2
South of Kanto	170 W/m2

Source: "Guidelines for the Design of Road Heating Equipment" by Association of Electricity and Telecommunication Engineering for Land and Infrastructure

3) Stock capacity of road heating

Based on the assumptions above, Fig. 2-113 shows the estimation results of the current and future stock capacity of road heating by region.

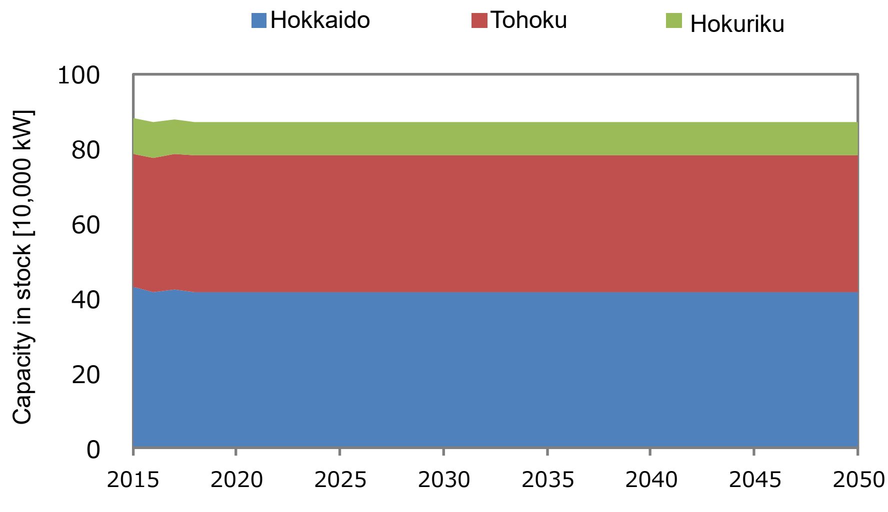


Fig. 2-113 Future stock capacity of road heating by region

(2) Current stock share by equipment type

As described, heat source equipment for snow melting is broadly classified into three types : heat pump, electric heating, and hot water. At present, the heat pump type is hardly widespread, and electric heating and hot water types are considered most popular. However, there is no official statistical data on the shipment and diffusion for each type of equipment, and it is impossible to accurately grasp the share of each type of equipment.

On the other hand, as far as Hokkaido is concerned, it is possible to grasp the general situation with existing literature and research (e.g., "Guidelines for the Maintenance of Snow-Melting Facilities (Draft): Efficient Use of Energy (2016)" by the Public Works Research Institute). In addition, in the "Survey on Trends in General Electricity Business Optional Supply Provisions" conducted by the Agency for Natural Resources and Energy of the Ministry of Economy, Trade and Industry in FY2012, it is possible to grasp the electricity consumption for snow-melting by region (power company), although only the actual figures for FY2011 are available.

Therefore, this Research estimated the stock share by equipment type separately for Hokkaido and Tohoku/Hokuriku Regions, using the literature, statistics, etc. mentioned above.

1) Hokkaido

a. Current stock share by equipment type

The current share of each type of equipment in Hokkaido was set as follows, based on the existing literature and research (e.g., "Guidelines for the Maintenance of Snow-Melting Facilities (Draft): Efficient Use of Energy (2016)" by the Public Works Research Institute).

- Electric heat type: 80%
- Hot water type: 20%
- Heat pump type: 0%

The validity of the setting (e.g., whether the estimated electricity consumption by electric heating exceeds the electricity consumption for snow melting in the entire Hokkaido) was confirmed by comparing the electricity consumption by electric road heating, which was calculated by multiplying the stock capacity of electric heating estimated with the setting above by the time equivalent to the full load, with the electricity consumption for snow-melting by Hokkaido Electric Power Co., Inc. specified in the Survey on Trends in General Electricity Business Optional Supply Provisions.

b. Full-load equivalent operating time of road heating

As for Hokkaido, the annual heat requirement (kWh/m2) per installation area is specified in the "Guidelines for the Maintenance of Snow-Melting Facilities (Draft): Efficient Use of Energy (2016)" by the Public Works Research Institute).

Therefore, the full load equivalent operating time of road heating in Hokkaido was calculated based on this value and the required heat generation per installation area (W/m2) mentioned above, as shown in Table 2-60.

Table 2-60 Calculation method of the full load equivalent operating time for road heating in Hokkaido

Used data		Source / Calculation method
(1) Required heat generation per area	250 W/m2	Values for Hokkaido (Central region) specified in "Design Guidelines for Road Heating Equipment" by Association of Electricity and Telecommunication Engineering for Land and Infrastructure
(2) Required annual heat generation per area	206.4 kWh/m2	Average values for FY 2011-2014 in Sapporo City, as indicated in the "Guidelines for the Maintenance of Snow-Melting Facilities (Draft): Efficient Use of Energy" by the Public Works Research Institute).
(3) Full load equivalent operating time	826 h/year	Estimated as (2)/(1).

c. Electricity consumption of electric road heating

Table 2-61 Based on the stock capacity of road heating in the Hokkaido region shown in (1) and the assumptions above, the electricity consumption by electric road heating was estimated to be 307 GWh, as shown in Table 2-61.

Electricity consumption of Hokkaido Electric Power for snow-melting (FY 2011 actual) was 1,252 GWh, according to "the Survey on Trends in General Electricity Business Optional Supply," which means that electric road heating accounts for about 25% of the total electricity consumption for snow-melting.

The electricity consumption for snow-melting in the "Survey on Trends in General Electricity Business Optional Supply" includes the electricity consumption for snow-melting at locations of general demand (e.g., store parking lot, etc.) other than road heating, which was the subject of this Research. In addition, the electricity consumption for snow-melting referred to herein is the electricity consumption in the electricity menu "for snow-melting" (a menu that covers a specified time zone in winter), which is generally considered appropriate considering that electricity is actually used for not only snow-melting but also heating, etc. in some cases.

In light of the above, the setting specified in "a" was decided to be used for the current stock share.

Table 2-61 Energy consumption for snow melting in Hokkaido

Data		Source / Calculation method
(1) Electricity consumption by electric road heating	307 GWh	Estimated as stock capacity (419,000 kW) x share of electric heating (80%) x full load equivalent operating time (826 h/year) / efficiency (0.9)
(2) Electricity consumption for snow-melting in the entire Hokkaido (actual figures for FY2011)	1,252 GWh	"Survey on Trends in General Electricity Business Optional Supply" The Agency of Natural Resources and Energy," Agency for Natural Resources and Energy, METI
(3) Share of electric road heating in (2) (%)	24.5%	Estimated as (1)/(2).

2) Tohoku and Hokuriku

For Tohoku and Hokuriku, since there is no statistical data on the current stock share by equipment type, the electricity consumption in electric heating was calculated by assuming the share of electric road heating in the electricity consumption for snow-melting specified in the "Survey on Trends in General Electricity Business Optional Supply," and estimated the stock capacity of electric heating by dividing the electricity consumption above by the total load equivalent time.

The remaining stock capacity is assumed to be all hot water type (0% for heat pump type), and then the stock share by equipment type was set.

a. Electricity consumption in electric heating type

For Tohoku and Hokuriku, of the electricity consumption for snow-melting specified in the Survey on Trends in General Electricity Business Optional Supply, the ratio of electric road heating was assumed to account for 50% of the total, and electricity consumption by electric heating was estimated as shown in Table 2-62.

Table 2-62 Estimation of electricity consumption by electric heating in Tohoku and Hokuriku Regions

Used data	Tohoku	Hokuriku	Source / Calculation method
(1) Electricity consumption for snow melting	306 GWh	61 GWh	"Survey on Trends in General Electricity Business Optional Supply" The Agency of Natural Resources and Energy," Agency for Natural Resources and Energy, METI
(2) Share of electric heating	50%	50%	Assumed value
(3) Electricity consumption by electric heating	153 GWh	30 GWh	Estimated as (1)x(2).

b. Full-load equivalent operating time in road heating

For Tohoku and Hokuriku, there was no existing statistics or literature on full load equivalent operating time in road heating. Therefore, assuming that the required annual heat value per area is proportional to the amount of snowfall, the required annual heat value per area was estimated by multiplying the aforementioned value for Hokkaido by the ratio of region-specific snowfall, which is published on the Japan Meteorological Agency's website, to the value of Hokkaido, and then the result was divided by the required heat value per area to estimate the full load equivalent operating time.

Table 2-63 shows the result of estimation. .

Table 2-63 Establishment of full load equivalent operating time for road heating in Tohoku and Hokuriku Regions

Region	Annual snowfall (Average for FY2010-2019)	Required annual heat generation per area	Required heat generation per area	Full load equivalent operating time
Hokkaido	4.53 m	206.4 kWh/m2	250 W/m2	826 h/year
Tohoku	2.52 m	114.8 kWh/m2	200 Wm2	574 h/year
Hokuriku	1.79 m	81.5 kWh/m2	200 Wm2	407 h/year

Note: Data of the prefectural capitals in the prefectures belonging to each region were used: data of Sapporo for Hokkaido; average data of Aomori, Morioka, Sendai, Akita, Yamagata, and Fukushima for Tohoku; and average data of Niigata, Toyama, Kanazawa, and Fukui for Hokuriku were used.

c. Current stock share by equipment type

The stock capacity of electric heating type was estimated from the aforementioned electricity consumption by electric heating and full load equivalent operating time. With the result of this estimation and the stock capacity of overall road heating in Tohoku and Hokuriku Regions shown in (1), the current share of electric heating type and hot water type was set as shown in Table 2-64.

Table 2-64 Stock capacity and stock share by equipment type in Tohoku and Hokuriku Regions

Data	Tohoku	Hokuriku	Source / Calculation method
(1) Stock capacity of road heating	366,000 kWh	89,000 kWh	From the estimation results shown in 1)
(2) Stock capacity of electric heating (Stock share)	240,000 kWh (66%)	67,000 kWh (76%)	Estimated as electricity consumption by electric heating x Efficiency (0.9) / Full load equivalent operating time.
(3) Stock capacity of hot water type (Stock share)	126,000 kWh (34%)	22,000 kWh (24%)	Estimated as (1)-(2). * Assumed the stock capacity of HPs to be 0%.

(3) Future stock share by equipment type

The future stock share of heat pump type was estimated by applying the logistic curve. In applying the logistic regression, as shown in Table 2-65, three cases of high, medium, and low were assumed as the upper asymptote of the heat pump type, and the diffusion speed was assumed to be the same as that of industrial heat pumps in "heating" and "low-temperature drying" of industrial heating.

Table 2-65 Assumption of the upper limit of introduction for snow-melting HPs

Case	Upper limit of HP introduction (upper limit of stock share)
High case	Stock capacity x 50%
Medium case	Stock capacity x 40%
Low case	Stock capacity x 30%

Based on the assumptions above, the stock shares of the heat pump type in the future snow-melting market for the high, medium, and low cases are shown in Fig. 2-114.

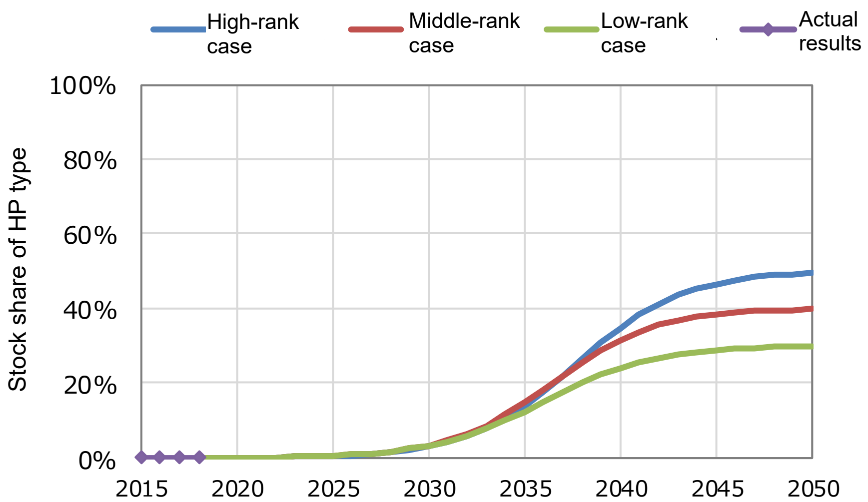


Fig. 2-114 Assumption of the stock share of the HP type in the future snow-melting market

The stock shares of electric heating and hot water types were assumed as shown in Table 2-66.

Table 2-66 Assumption of the stock share of electric heating and hot water types in the future snow-melting market

Type	Stock share assumption
Electric heating	(100% - stock share of HP) x Current stock share of electric heating
Hot water	(100% - stock share of HP) x Current stock share of hot water type

(4) Average number of years of use

The average number of years of use was set at 20 years in accordance with the assumption in the "Guidelines for the Maintenance of Snow-Melting Facilities (Draft): Efficient Use of Energy (2016)" by the Public Works Research Institute).

(5) Flow efficiency of snow-melting equipment

The flow efficiency of snow-melting equipment by type was set as shown in Fig. 2-115.

The efficiency of the heat pump type was set for the current year (FY2018) based on the efficiency of heat pumps for snow melting that are currently available on the market, which was surveyed by HPTCJ. The future efficiency was assumed to achieve, in FY2050, 0.9 times the cold-weather efficiency of commercial heat pump water heaters in the same year, with linear interpolation.

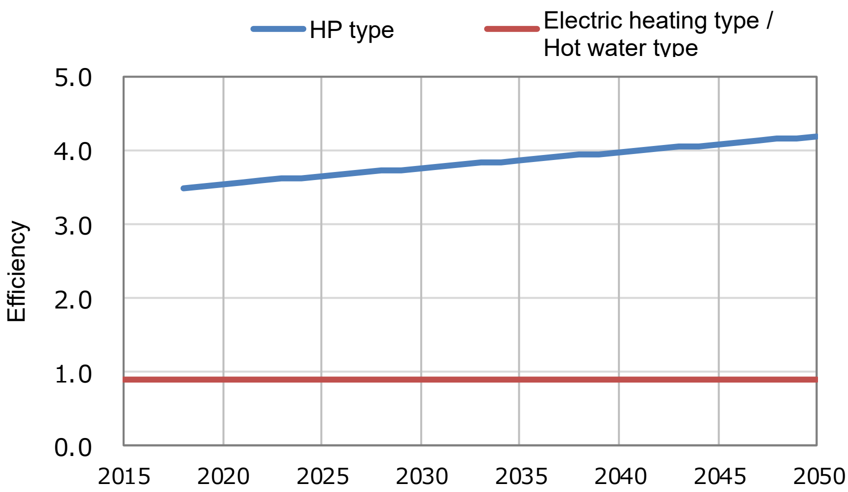


Fig. 2-115 Assumption of flow efficiency of snow-melting equipment by type

2.8.4 Calculation results

(1) Shipping capacity / stock capacity

The estimation results of the shipping capacity and stock capacity of the heat pumps types based on the assumptions above are shown in Fig. 2-116 and Fig. 2-117, respectively.

Shipment capacity is expected to grow rapidly around FY2040, then decline until around FY2050, and then expand again. This is considered to represent the accelerated introduction into the market where the economic advantage over electric heating and hot water types works and a subsequent drop-off when the market is saturated. After around FY2050, it is expected to expand again due to demand for the replacement of heat pump type that was once introduced.

In either case, the stock capacity is expected to almost reach the upper limit of introduction by around FY2050.

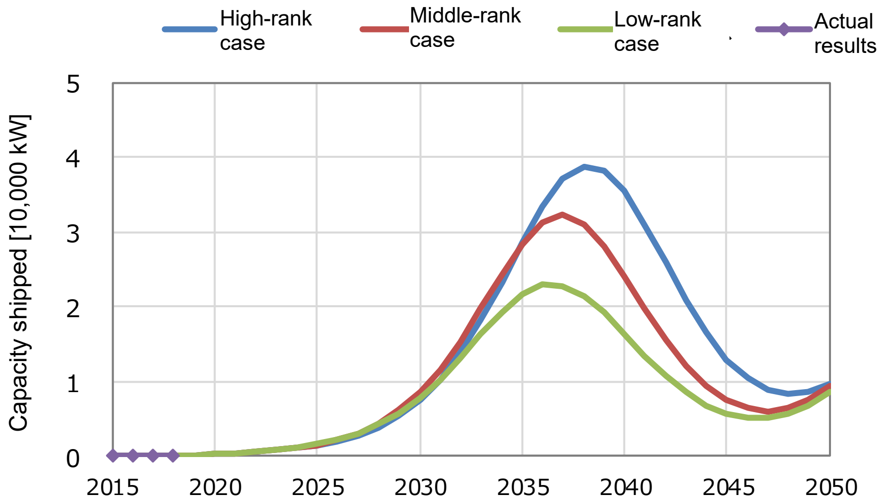


Fig. 2-116 Estimation results of the shipping capacity of snow-melting HPs

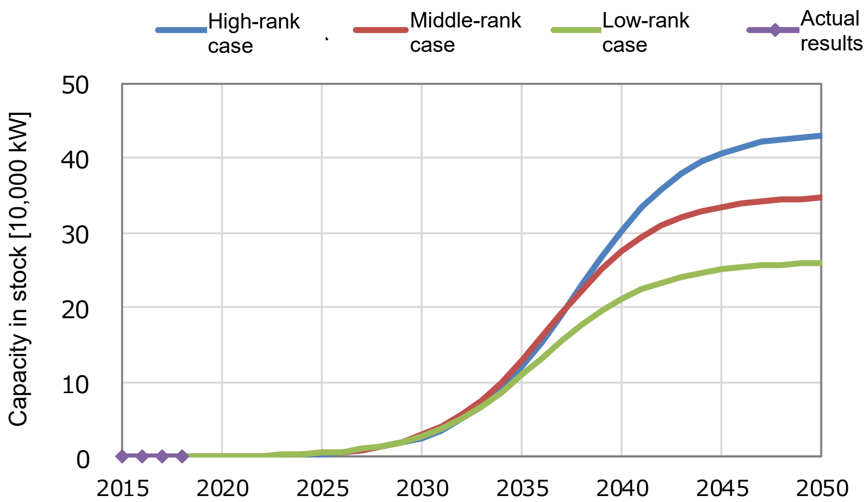


Fig. 2-117 Estimation results of the stock capacity of snow-melting HPs

(2) Primary energy consumption, energy saving effect, CO2 reduction effect

Fig. 2-118 shows the calculation results of the primary energy consumption based on the estimation results of shipping capacity and stock capacity above, and the assumed flow efficiency, full load equivalent operating time, and primary energy conversion factor for electricity.

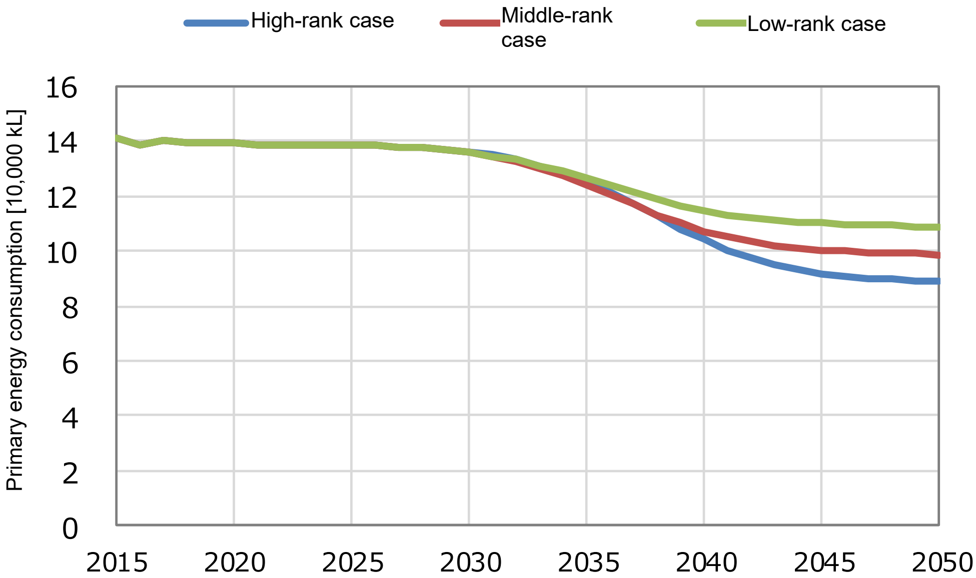


Fig. 2-118 Estimation results of primary energy consumption: Snow melting

Based on the results above, Fig. 2-119 and Table 2-67 show the energy-saving effects (effect of reduction in primary energy consumption) from the fixed status case for each case, assuming that the current (FY2018) stock share and flow efficiency of the heat pump type will remain constant in the future.

The energy savings in the medium case for the FY2050 cross section is estimated to be 40,000 kL/year, of which the replacement effect of the electric heating and hot water types is estimated to be 38,000 kL/year and the efficiency improvement effect of the heat pump type is estimated to be 2,000 kL/year.

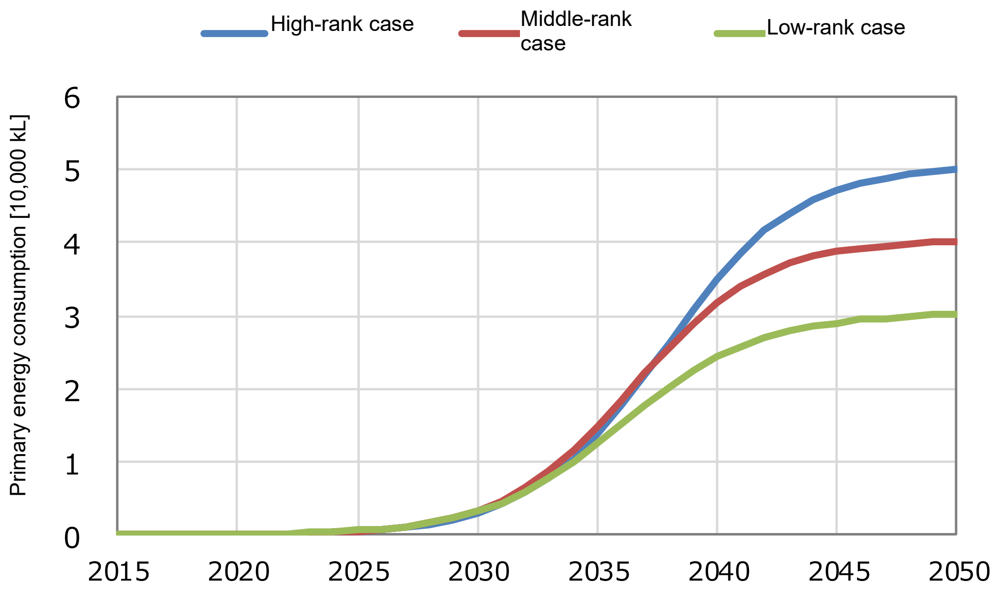


Fig. 2-119Estimation results of energy saving effect: Snow melting

Table 2-67Breakdown of energy saving effect: Snow melting

Case	Breakdown	Energy saving effect (10,000 kL/year)			
		FY2020	FY2030	FY2040	FY2050
High case	Total	0.0	0.3	3.5	5.0
	Alternative effect of electric heating and hot water types	0.0	0.3	3.4	4.8
	Efficiency improvement effect of HP type	0.0	0.0	0.1	0.2
Medium case	Total	0.0	0.3	3.2	4.0
	Alternative effect of electric heating and hot water types	0.0	0.3	3.0	3.8
	Efficiency improvement effect of HP type	0.0	0.0	0.1	0.2
Low case	Total	0.0	0.3	2.4	3.0
	Alternative effect of electric heating and hot water types	0.0	0.3	2.3	2.9
	Efficiency improvement effect of HP type	0.0	0.0	0.1	0.1

Note: Due to rounding, the sum of each value does not necessarily equal the total value shown.

Fig. 2-120 and Table 2-68 show the CO_2 reduction effect estimated by multiplying the above energy saving effect by CO_2 intensity. There are two types of fuels for hot water type: city gas and kerosene. Since the breakdown of these fuels is not known, the average of the emission factors for city gas and kerosene is used here as the same ratio and assumed to be constant in the future.

The CO_2 reduction effect in the medium case for the FY2050 cross section is estimated to be 30,000 t-CO_2/year, of which the replacement effect of the electric heating and hot water types is estimated to be 29,000 t-CO_2/year and the efficiency improvement effect of the heat pump type is estimated to be 1,000 t-CO_2/year. The CO_2 reduction effect will increase toward the early 2040s, and then begin to decrease. This is because the impact of the declining effect of CO_2 reduction per unit of energy saving becomes more significant as the reduction of CO_2 intensity of electricity progresses over the medium to long term.

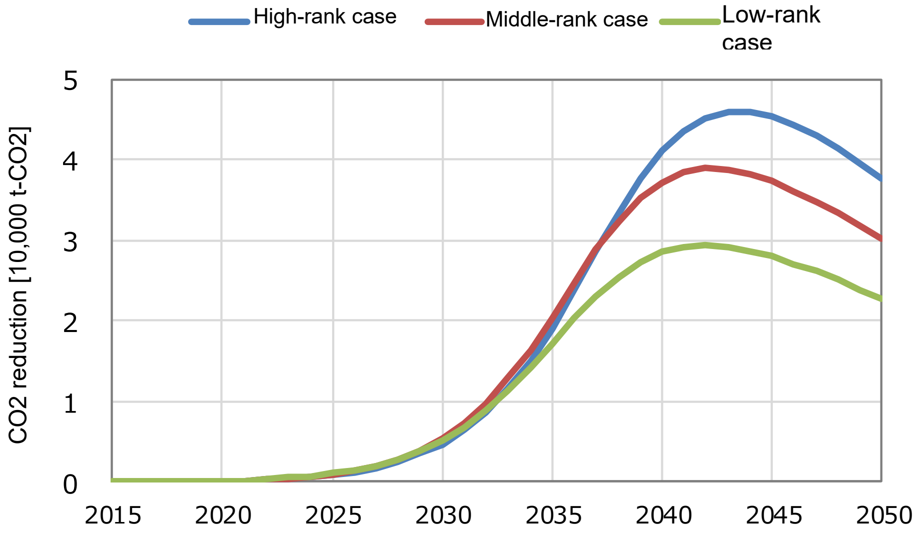


Fig. 2-120 Estimation results of CO_2 reduction effect: Snow melting

Table 2-68Breakdown of the CO_2 reduction effect: Snow melting

Case	Breakdown	CO2 reduction effect (10,000 t-CO2/year)			
		FY2020	FY2030	FY2040	FY2050
High case	Total	0.0	0.5	4.1	3.8
	Alternative effect of electric heating and hot water types	0.0	0.5	4.0	3.7
	Efficiency improvement effect of HP type	0.0	0.0	0.1	0.1
Medium case	Total	0.0	0.5	3.7	3.0
	Alternative effect of electric heating and hot water types	0.0	0.5	3.6	2.9
	Efficiency improvement effect of HP type	0.0	0.0	0.1	0.1
Low case	Total	0.0	0.5	2.9	2.3
	Alternative effect of electric heating and hot water types	0.0	0.5	2.8	2.2
	Efficiency improvement effect of HP type	0.0	0.0	0.1	0.1

Note: Due to rounding, the sum of each value does not necessarily equal the total value shown.

3. Summarization

3.1 Results of analysis on the expanded diffusion of heat pumps

The effects of the expanded diffusion of heat pumps in each sector, which were obtained in this research, are summarized below. As a case assuming that no special measures are taken, we set a fixed status case assuming that the stock share and flow efficiency of heat pump equipment in the current fiscal year 2018 remain constant in the future, and organized the energy saving effect, the reduction effect of CO2 emissions, and the increase and decrease of electricity consumption in each case (high case, medium case, and low case) in which the diffusion of heat pumps expanded, against the current fixed case.

3.1.1 Reduction effect of primary energy consumption

Fig. 3-1 shows the energy saving effect (effect of reduction in primary energy consumption) from the case fixed to current status based on the FY2018, Fig. 3-2 shows the breakdown by application in the medium case, and Table 3-1 to Table 3-3 show the values of each application in each case. The energy saving in the medium case is estimated to be 6.56 million kL/year in the FY2030 cross section and 24.11 million kL/year in the FY2050 cross section.

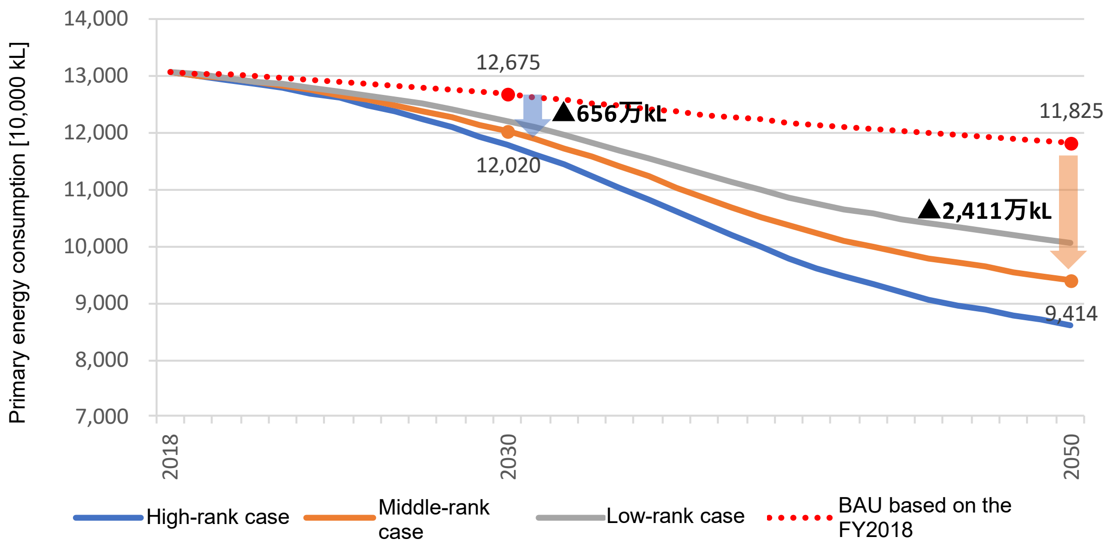


Fig. 3-1 Reduction effect of primary energy consumption

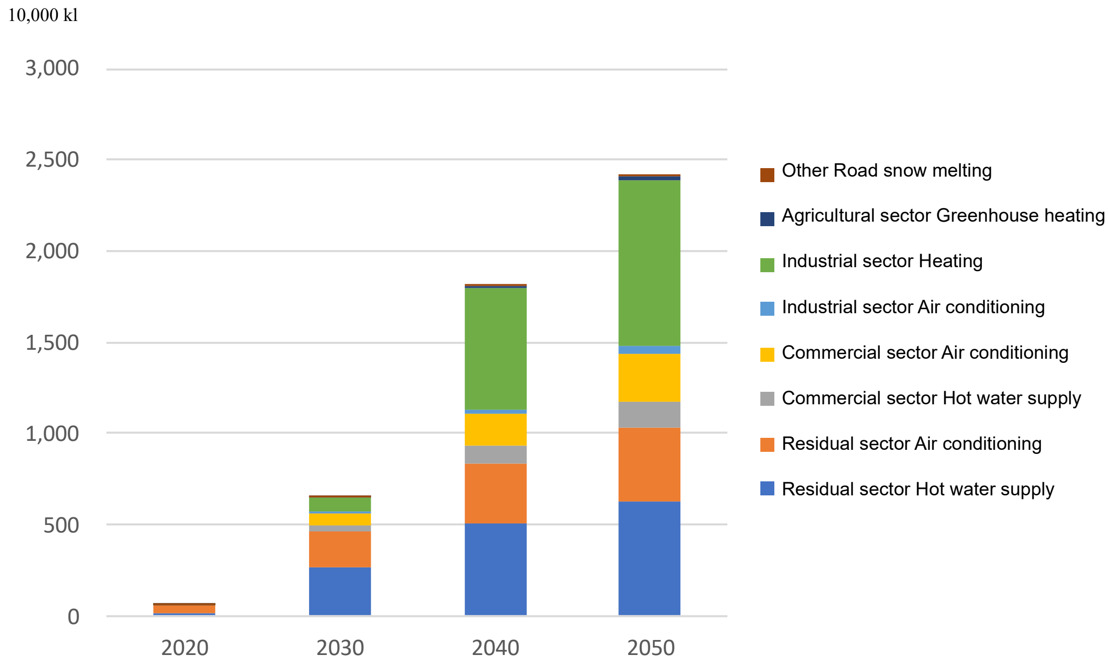


Fig. 3-2 Reduction effect of primary energy consumption: Medium case

Table 3-1Reduction effect of primary energy consumption: High case

Use		Energy saving effect (10,000 kL/year)			
		FY2020	FY2030	FY2040	FY2050
Residential sector	Hot water supply	22	400	809	1,001
	Air conditioning	42	252	412	494
Commercial sector	Hot water supply	1	33	151	224
	Air conditioning	5	91	209	302
Industrial sector	Air conditioning	1	13	30	44
	Heating	1	85	754	1,112
Agricultural sector	Greenhouse heating	0	14	24	28
Other	Snow melting	0	0	4	5
Total		73	889	2,393	3,209

Note: Due to rounding, the sum of each value does not necessarily equal the total value shown.

Table 3-2eduction effect of primary energy consumption: Medium case

Application		Energy saving effect (10,000 kL/year)			
		FY2020	FY2030	FY2040	FY2050
Residential sector	Hot water supply	21	262	507	632
	Air conditioning	34	203	330	396
Commercial sector	Hot water supply	1	26	102	148
	Air conditioning	4	69	170	261
Industrial sector	Air conditioning	1	10	25	39
	Heating	1	75	665	913
Industrial sector	Greenhouse heating	0	9	14	17
Other	Snow melting	0	0	3	4
Total		62	656	1,817	2,411

Note: Due to rounding, the sum of each value does not necessarily equal the total value shown.

Table 3-3 Reduction effect of primary energy consumption: Low case

Application		Energy saving effect (10,000 kL/year)			
		FY2020	FY2030	FY2040	FY2050
Residential sector	Hot water supply	18	168	312	390
	Air conditioning	26	149	243	294
Commercial sector	Hot water supply	1	20	68	98
	Air conditioning	3	46	127	218
Industrial sector	Air conditioning	1	7	19	33
	Heating	1	70	541	708
Industrial sector	Greenhouse heating	0	5	8	10
Other	Snow melting	0	0	2	3
Total		50	467	1,322	1,754

Note: Due to rounding, the sum of each value does not necessarily equal the total value shown.

3.1.2 Reduction effect of CO2 emissions

Fig. 3-3 shows the CO2 reduction effect from the case fixed to current status based on the FY2018, Fig. 3-4 shows the breakdown by application in the medium case, and Table 3-4 to Table 3-6 show the values of each application in each case. The amount of CO2 reduction in the medium case is estimated to be 17.65 million t-CO2/year in the FY2030 cross section and 71.38 million t-CO2/year in the FY2050 cross section.

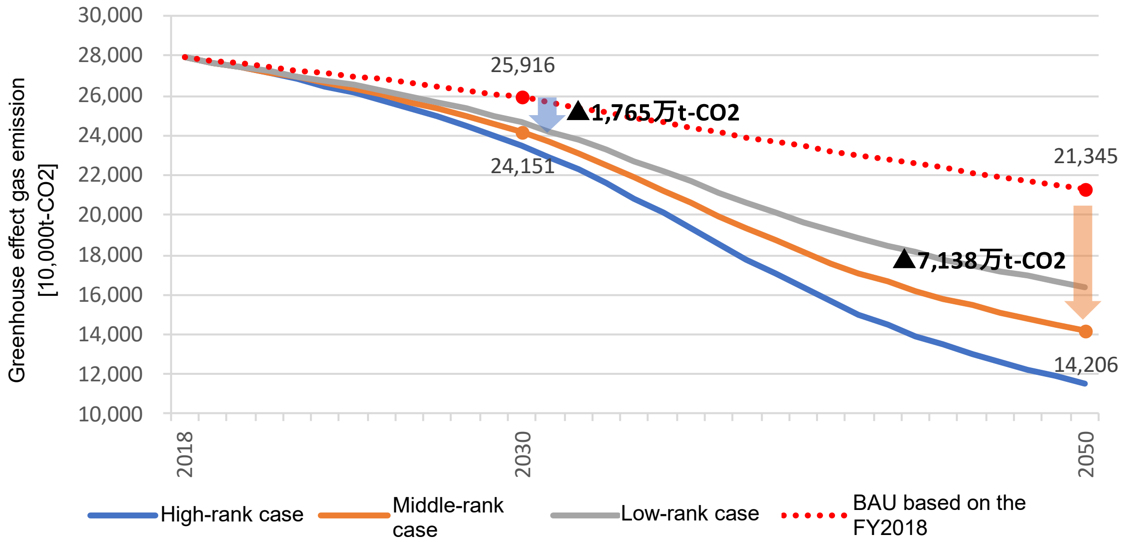


Fig. 3-3 Reduction effect of CO2 emissions

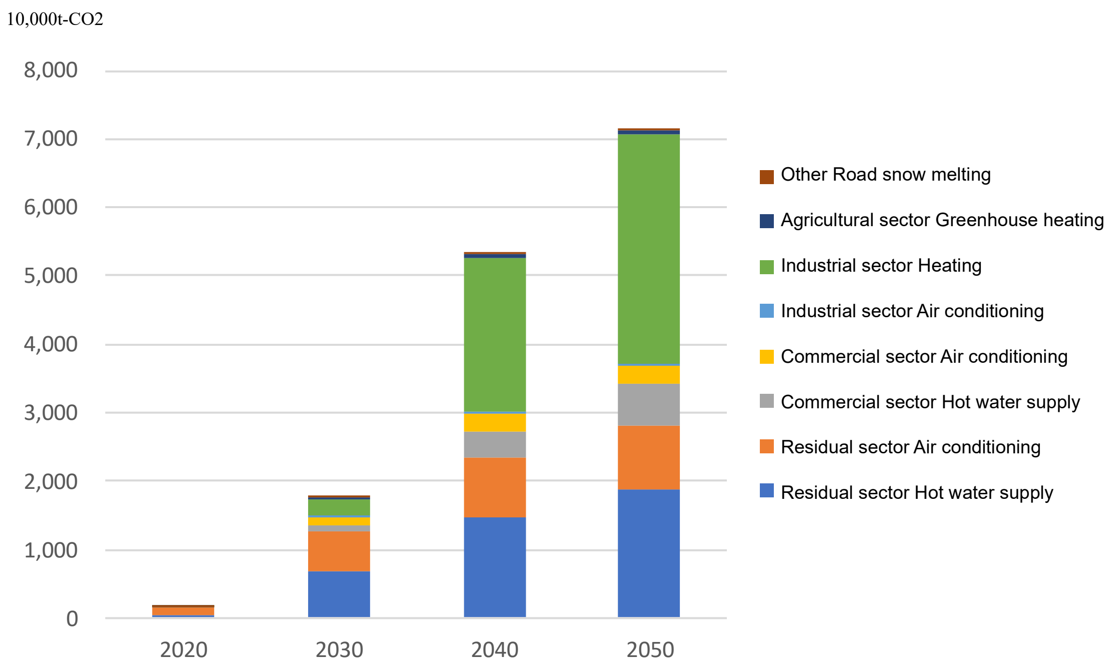


Fig. 3-4 Reduction effect of CO2 emissions: Medium case

Table 3-4 Reduction effect of CO2 emissions: High case

Application		CO2 reduction effect (10,000 t-CO2/year)			
		FY2020	FY2030	FY2040	FY2050
Residential sector	Hot water supply	53	1,039	2,361	3,037
	Air conditioning	121	723	1,135	1,263
Commercial sector	Hot water supply	2	113	593	912
	Air conditioning	17	188	325	333
Industrial sector	Air conditioning	3	26	45	46
	Heating	3	256	2,562	4,104
Industrial sector	Greenhouse heating	1	52	93	110
Other	Snow melting	0	0	4	4
Total		199	2,397	7,118	9,808

Note: Due to rounding, the sum of each value does not necessarily equal the total value shown.

Table 3-5 Reduction effect of CO2 emissions: Medium case

Application		CO2 reduction effect (10,000 t-CO2/year)			
		FY2020	FY2030	FY2040	FY2050
Residential sector	Hot water supply	49	677	1,462	1,878
	Air conditioning	98	575	874	938
Commercial sector	Hot water supply	2	88	397	601
	Air conditioning	13	142	253	261
Industrial sector	Air conditioning	2	21	37	38
	Heating	2	228	2,250	3,354
Agricultural sector	Greenhouse heating	1	32	56	67
Other	Snow melting	0	1	4	3
Total		167	1,765	5,332	7,138

Note: Due to rounding, the sum of each value does not necessarily equal the total value shown.

Table 3-6 Reduction effect of CO2 emissions: Low case

Application		CO2 reduction effect (10,000 t-CO2/year)			
		FY2020	FY2030	FY2040	FY2050
Residential sector	Hot water supply	44	428	877	1,116
	Air conditioning	76	414	599	602
Commercial sector	Hot water supply	2	69	265	393
	Air conditioning	9	94	177	186
Industrial sector	Air conditioning	2	15	28	29
	Heating	2	209	1,812	2,579
Industrial sector	Greenhouse heating	1	19	31	38
Other	Snow melting	0	1	3	2
Total		135	1,250	3,793	4,945

Note: Due to rounding, the sum of each value does not necessarily equal the total value shown.

Fig. 3-5 shows the effect of CO2 reduction based on FY2018 emissions, and Fig. 3-6 shows the breakdown of applications in the medium case. CO2 reduction in the medium case is estimated to be 37.54 million t-CO2/year in the FY2030 cross section and 136.99 million t-CO2/year in the FY2050 cross section.

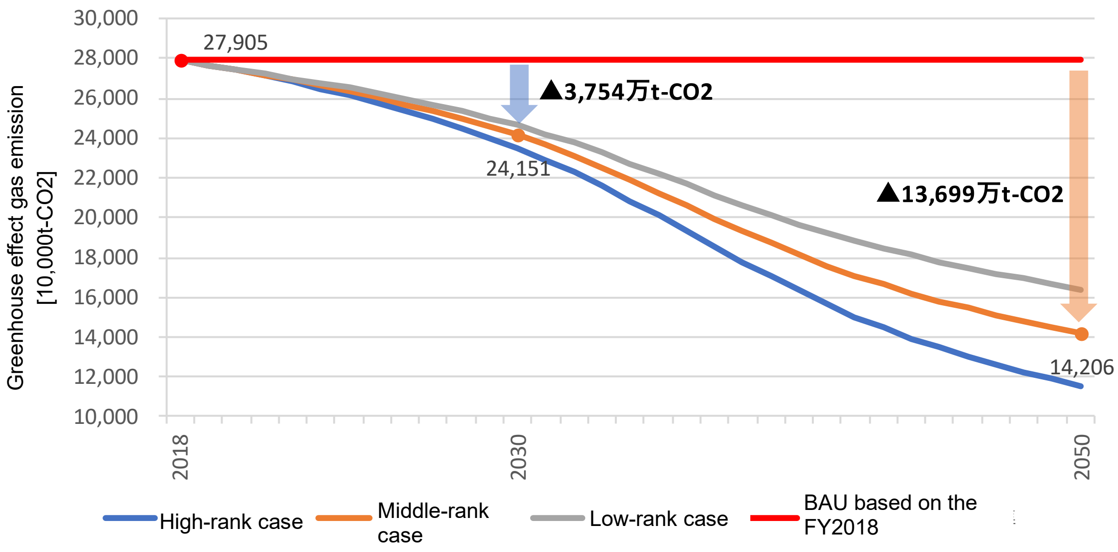


Fig. 3-5 Reduction effect of CO2 emissions (based on FY2018 emissions)

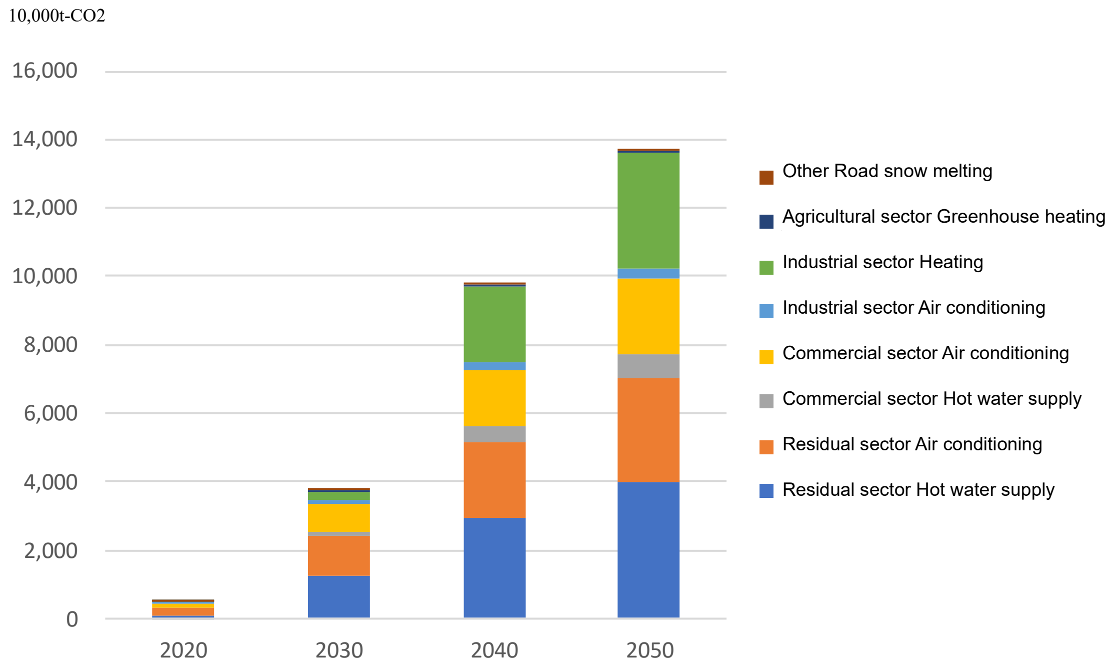


Fig. 3-6 Reduction effect of CO2 emissions (based on FY2018 emissions): Medium case

3.1.3 Reduction effect of final energy consumption

Fig. 3-7 shows the reduction effect of final energy consumption from the case fixed to current status based on the FY2018, Fig. 3-8 shows the breakdown by application in the medium case, and Table 3-7 to Table 3-9 show the values of each application in each case. The reduction of final energy consumption in the medium case is estimated to be 9.14 million kL/year in the FY2030 cross section and 31.32 million kL/year in the FY2050 cross section.

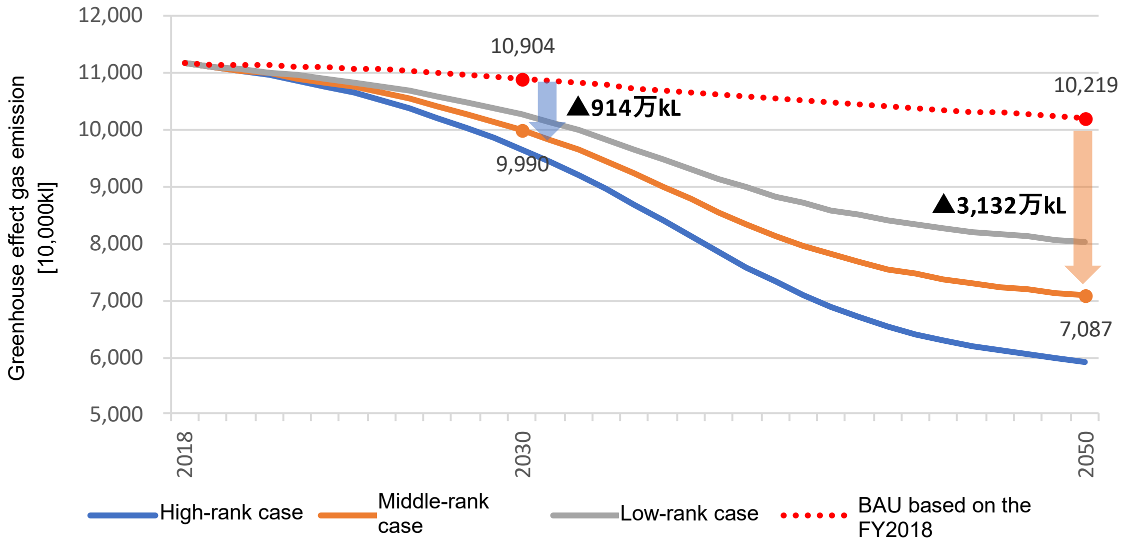


Fig. 3-7 Reduction effect of final energy consumption

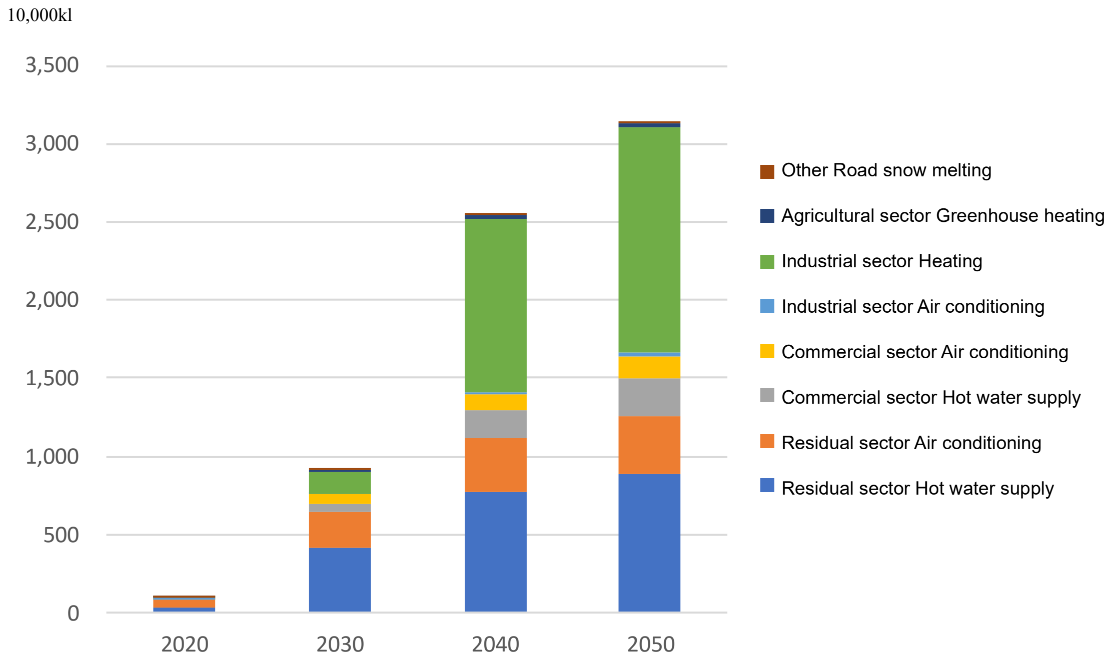


Fig. 3-8 Reduction effect of final energy consumption: Medium case

Table 3-7 Reduction effect of final energy consumption: High case

Application		Reduction effect of final energy consumption (10,000 kL/year)			
		FY2020	FY2030	FY2040	FY2050
Residential sector	Hot water supply	35	635	1,246	1,421
	Air conditioning	57	301	446	501
Commercial sector	Hot water supply	1	62	270	363
	Air conditioning	10	75	135	177
Industrial sector	Air conditioning	2	10	19	25
	Heating	2	154	1,268	1,768
Agricultural sector	Greenhouse heating	1	21	34	38
Other	Snow melting	0	0	2	2
Total		108	1,260	3,420	4,295

Note: Due to rounding, the sum of each value does not necessarily equal the total value shown.

Table 3-8 Reduction effect of final energy consumption: Medium case

Application		Reduction effect of final energy consumption (10,000 kL/year)			
		FY2020	FY2030	FY2040	FY2050
Residential sector	Hot water supply	33	415	773	883
	Air conditioning	46	234	338	376
Commercial sector	Hot water supply	1	49	180	239
	Air conditioning	8	56	104	143
Industrial sector	Air conditioning	1	8	15	21
	Heating	1	138	1,113	1,445
Agricultural sector	Greenhouse heating	1	13	21	23
Other	Snow melting	0	0	1	2
Total		91	914	2,547	3,132

Note: Due to rounding, the sum of each value does not necessarily equal the total value shown.

Table 3-9 Reduction effect of final energy consumption: Low case

Application		Reduction effect of final energy consumption (10,000 kL/year)			
		FY2020	FY2030	FY2040	FY2050
Residential sector	Hot water supply	29	263	464	529
	Air conditioning	35	162	225	246
Commercial sector	Hot water supply	1	38	121	157
	Air conditioning	6	37	72	109
Industrial sector	Air conditioning	1	6	11	17
	Heating	1	126	896	1,112
Agricultural sector	Greenhouse heating	1	8	12	13
Other	Snow melting	0	0	1	1
Total		74	639	1,802	2,184

Note: Due to rounding, the sum of each value does not necessarily equal the total value shown.

3.1.4 Increase / decrease in electricity consumption

Fig. 3-9 shows the variation of electricity consumption from the case fixed to current status based on the FY2018, Fig. 3-10 shows the breakdown by application in the medium case, and Table 3-10 to Table 3-12 show the values of each application in each case. The electricity consumption in the medium case is estimated to be 16.3 billion kL/year in the FY2030 cross section and 45.4 billion kL/year in the FY2050 cross section.

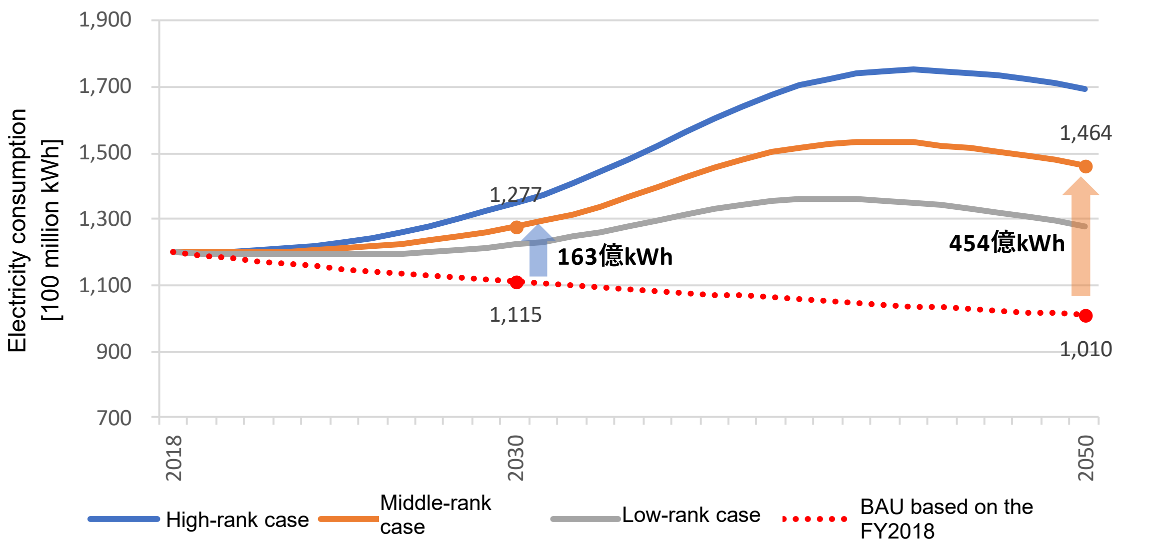


Fig. 3-9 Variation of electricity consumption

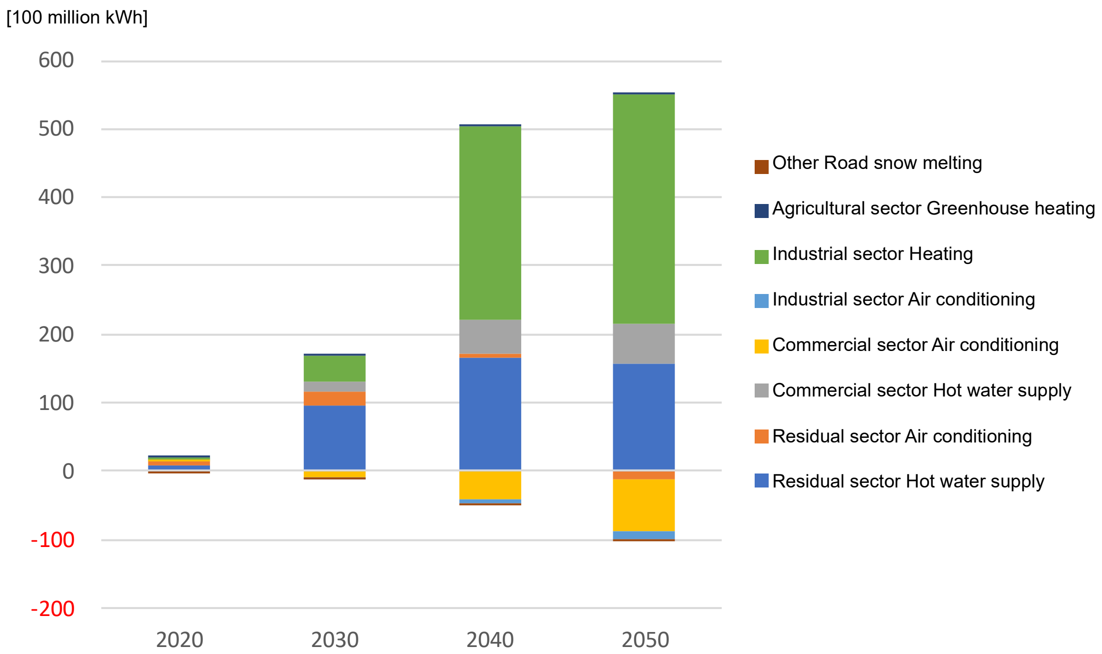


Fig. 3-10 Variation of electricity consumption: Medium case

Table 3-10 Variation of electricity consumption: High case

Application		Increase/decrease in electricity consumption (100 million kWh/year)			
		FY2020	FY2030	FY2040	FY2050
Residential sector	Hot water supply	8	148	276	264
	Air conditioning	9	31	22	4
Commercial sector	Hot water supply	0	18	75	88
	Air conditioning	3	-10	-47	-79
Industrial sector	Air conditioning	0	-2	-7	-12
	Heating	1	43	324	413
Agricultural sector	Greenhouse heating	0	5	7	6
Other	Snow melting	-0	-0	-1	-2
Total		22	233	647	683

Note: Due to rounding, the sum of each value does not necessarily equal the total value shown.

Table 3-11 3-11Variation of electricity consumption: Medium case

Application		Increase/decrease in electricity consumption (100 million kWh/year)			
		FY2020	FY2030	FY2040	FY2050
Residential sector	Hot water supply	8	96	167	158
	Air conditioning	7	20	6	-13
Commercial sector	Hot water supply	0	14	50	57
	Air conditioning	3	-8	-41	-74
Industrial sector	Air conditioning	0	-1	-6	-11
	Heating	0	39	282	335
Agricultural sector	Greenhouse heating	0	3	4	4
Other	Snow melting	-0	-0	-1	-1
Total		19	163	459	454

Note: Due to rounding, the sum of each value does not necessarily equal the total value shown.

Table 3-12 Variation of electricity consumption: Low case

Application		Increase/decrease in electricity consumption (100 million kWh/year)			
		FY2020	FY2030	FY2040	FY2050
Residential sector	Hot water supply	7	60	96	87
	Air conditioning	5	8	-12	-31
Commercial sector	Hot water supply	0	11	33	37
	Air conditioning	2	-6	-35	-69
Industrial sector	Air conditioning	0	-1	-5	-10
	Heating	0	36	224	255
Agricultural sector	Greenhouse heating	0	2	2	2
Other	Snow melting	-0	-0	-1	-1
Total		15	109	302	270

Note: Due to rounding, the sum of each value does not necessarily equal the total value shown.

3.2 For expanding the diffusion of heat pumps

As the target markets for heat pumps, this research focused on the residential sector (hot water supply, air conditioning), commercial sector (hot water supply, air conditioning), industrial sector (air conditioning, heating), agricultural sector (greenhouse heating), and other sector (snow-melting), and analyzed their prospects in Japan until FY2050 and the effects of reducing primary energy and greenhouse gases by expanding the diffusion.

As a result of the analysis, the reduction effects of primary energy consumption and CO2 emissions in the medium case (compared to the case of fixing current state based on FY2018) when boilers, etc., that cover the heat demand of each sector are replaced by heat pump equipment were as follows.

FY2030: Primary energy consumption: -6.56 million kl, CO2 emissions: -17.65 million t-CO2

FY2050: Primary energy consumption: -24.11 million kl, CO2 emissions: -71.38 million t-CO2

High level of energy saving is mentioned as the most significant feature of heat pumps, and the expanded diffusion of heat pumps is expected to greatly contribute to the reduction of CO2 emissions, through the synergistic effect of the shift to electrification technology on the demand side and the progress of low-carbon power sources on the power supply side. In addition, heat pump water heaters and thermal storage heat pump air conditioning systems are expected to play a role in supporting the low-carbon electric power systems using natural energy through utilization of demand adjustment , which is necessary for the diffusion of renewable energy.

Accordingly, heat pumps are expected to play an even more important role in realizing the progress of thorough energy saving and the long-term transition to a decarbonized energy supply and demand structure, which Japan should aim for, and we should aim for realization of the high case presented in this analysis. However, the realization would not be easy as an extension of the current status, and efforts to expand the diffusion are required.

There is a concern that energy utilization technologies in consumer facilities are subject to the lock-in effect, i.e., once the infrastructure is built, the same type of technology will continue to be selected for renewal. Therefore, in order to realize the transition to a decarbonized energy supply and demand structure, it is extremely important to implement measures at the time of new construction of facilities.

In the consumer sector, for new houses and buildings, it should be promoted to realize houses and buildings (ZEH, ZEB) where net energy consumption becomes approximately zero or less by further strengthening the Building Energy Conservation Law, for example, and the introduction of heat pumps with excellent energy consumption efficiency is considered effective as a technological option to realize such houses and buildings. In the market for existing houses and buildings, it is difficult to take drastic measures for air conditioning and hot water supply, which are energy intensive applications, but heat source measures are easier to take compared to building insulation retrofitting, By strengthening heat source measures, it is necessary to overcome various issues, such as constraints on installation space, piping infrastructure, etc. to expand the introduction of heat pumps.

In the industrial sector, it is now common to generate high-pressure steam in the steam boiler installed in the boiler room, etc. in the factory, and then supply the steam to process equipment in each building while reducing the steam pressure. As the technology of heat pumps improves and product development progresses, we should aim for a new factory heat utilization system that enables efficient heat supply by introducing the appropriate temperature and amount of heat pumps in a consistent manner for each heat process in the factory. To this end, it is required, for example, to strengthen the engineering capability to build an optimal system for various heat processes, reduce the burden on consumers for system costs including not only equipment cost but also design cost, and further expand the range of applications of industrial heat pumps by increasing their temperature and capacity.

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